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CONTENTS

FEATURES

DEPARTMENTS

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HORIZON—A Digital Library Project for Earth and Space Data Serving the Public

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Project Horizon is a multifaceted project that seeks to enhance digital library technology, specifically World Wide Web (WWW) client and server technology, in support of easy to use and scalable public access for locating, moving, and analyzing both Earth and space science data. The project is funded by NASA and centered at the National Center for Supercomputing Applications (NCSA), the developer of NCSA Mosaic and the hierarchical data format (HDF) now being used in the Earth Observing System (EOS) project. Activities integrate and leverage off of existing research, development, and discipline-specific activities at NCSA and at the University of Illinois Departments of Astronomy, Atmospheric Sciences, Computer Science, and Library and Information Science. Client side efforts include the implementation of the Interactive Image Client Environment (IICE), providing enhanced functionality on the client (user) machine. Server side developments involve HDF and netCDF file browsing capabilities and file format conversions. Research and development areas include efficient access to large data sets, scalable server technologies, and next-generation information systems. Finally, there are two WWW testbed servers, one for Earth science (The Daily Planet™) and one for space science (Astronomy Digital Image Library), that provide working real world applications to thoroughly test and demonstrate the above technologies.

Interactive images

IICE extends the interactive capabilities of traditional Web environments using client hardware capabilities. This enables the genera-

The purpose of the SCIENCE INFORMATION SYSTEMS NEWSLETTER is to inform the space science and applications research community about information systems development and to promote coordination and collaboration by providing a forum for communication. This quarterly publication focuses on programs sponsored by the Information Systems Branch in support of NASA's Office of Space Science. Articles of interest for other programs and agencies are presented as well.

tion of customized interactive products on the client machine that would be too costly to produce in mass on the server. This approach scales with increasing users, each with a personal computer, whereas scaling a server environment to meet demand requires the addition of new server machines.

IICE is being developed using the Java environment from Sun Microsystems. It consists of an object-oriented Java language, a Java interpreter, and any Java-capable WWW browser (one that has the interpreter imbedded in it). Java-capable browsers are being developed for many of the common platforms including UNIX, Mac, and Windows. Use of this capability means that applications (called applets) can be written once in Java and then executed on any of these clients rather than writing the application for each platform. The interface/output then appears directly inside a hypertext markup language (HTML) document.

Initially applets have been written to interpret images through translation of pixel values into physical quantities (e.g., a radiance level into temperature), to overlay vector plots/images, and to allow animation with direction and speed under user control [4]. These applets form part of the new University of Illinois at Urbana -Champaign (UIUC) Weather Visualizer prototype that can be accessed on the WWW at:

http://storm.atmos.uiuc.edu/java/

Several future development paths are under discussion. One involves duplicating some of the functionality of a meteorological display and analysis system within the Java environment, so that only raw data needs to be downloaded from the server. Once that raw data exists on the client computer, it could be processed, formatted, and displayed according to the needs and specifications of the user, with no further server intervention.

Alternatively, data can be manipulated on the server and then displayed with the aid of smaller, specific-purpose analysis applets on the client. These could range from the graphical display of various forecast model parameters to more specific tools such as interactively estimating cloud top height given infrared imagery and atmospheric soundings or displaying a plot of various meteorological variables as a function of distance along a line drawn on a map.

The scientific data server

Several efforts are underway to provide additional capabilities related to the use of HDF and the WWW. A server side HDF browser has been developed for displaying HDF browse versions of images, tables, arrays, attributes, and text. One prototype version of this scientific data server/browser (SDS) provides access to "objects" stored in HDF (http://hdf.ncsa.uiuc.edu:4321/). By using the new subsetting and subsampling capabilities of HDF 4.0, the server also allows users to extract subsets and subsamples from HDF arrays. Because the resulting HTML documents contain tables of ascii values, these numbers can be easily copied and pasted into other applications, such as spreadsheets, for further analysis and computation. A simple search engine has also been constructed to retrieve data based on keyword matching of metadata parameters and full-text search of annotations and attribute values.

Another prototype version is currently being used for Coastal Zone Color Scanner (CZCS) files at GSFC's Distributed Active Archive Center (DAAC) (http://daac.gsfc.nasa.gov/WORKINPROGRESS/OCDST/czcs_data.html). Currently, there are two versions of the HDF browser/server configured to facilitate browsing for Level 2 and Level 3 CZCS products. Level 2 products include the North Atlantic Region (1981), classic images of interest, and the Chesapeake Bay Region. Level 3 products include regional and global composites such as the (1X1) chlorophyll mean. In these versions, images are converted into GIF format and embedded within HTML pages. This conversion is done on the server but will be extended to the client in the future, provided that the client has a working version of HDF installed.

The current HDF server/browser supports netCDF data (not image) files. In addition, two-way conversion between flexible image transport system (FITS), a commonly used format in observational astronomy, and HDF extends the usefulness of the browser for the Astronomy Digital Image Library (ADIL) (http://hdf.ncsa.uiuc.edu:8001/fits/).

Large multidimensional arrays are a common data type in high-performance scientific applications. In addition, large arrays will become increasingly available through the WWW. Without special techniques for handling access to these arrays, I/O can easily become a large fraction of execution time for scientific and information applications using these arrays, especially on parallel platforms. The Persistence and Arrays (Panda) software library (http://bunny.cs.uiuc.edu/CADR/panda.html) provides high-level abstract interfaces that free the application developer from the need to consider low-level physical storage details to reach acceptable I/O performance levels. It also provides advanced I/O support through efficient layout alternatives (appropriate chunking of the array) on disk and in main memory for large multidimensional arrays in addition to support for high-performance array I/O operations. The high-level interfaces for the array I/O operations provide ease of use and enhance the portability of an application.

Panda is built on top of existing commodity file systems such as AIX. The high-level interfaces provide ease of use, application portability, and, most importantly, allow plenty of flexibility for an efficient underlying implementation. The Panda I/O library exhibits excellent performance on the massively parallel SP2, attaining 83–98% of peak AIX performance on each I/O node in test experiments. It shows excellent scalability with data size and increased number of processors, and it provides very high throughput compared to ordinary AIX file system performance. These results can be traced to Panda's use of 'server-directed I/O', the high-level user interface, and built-in facilities to rearrange arrays from one physical schema to another during I/O. There is also a Sun version and ports to other systems are underway.

Research within the HORIZON project is aimed at improving access time for sub-sampling large arrays. This is expected to be a major bottleneck for accessing large remotely sensed images on servers and in parallel environments.

Information systems research

The Net of the twenty-first century will have a very different character than at present. There will be billions of repositories, both large and small, maintained and indexed by many communities. These repositories are organized collections of information, each with indices and a search engine. For example, one repository might include journal articles with a sophisticated search engine that can look for words and word patterns in the main text, in figure captions, or in tables. Another could include large scientific data sets such as those kept at NASA DAAC sites along with a pattern recognition search engine and notes from scientists studying the data. These capabilities go well beyond what current WWW browsing and server capabilities provide. Because of the large number of these distributed repositories substantial organization and cross-correlation of information is needed in order to most effectively make use of them. A typical session with the Net in the future will be a reference session in a large library where you move through interlinked resources seeking information. In a digital library, you will navigate through multiple interlinked network-based resources around the world to explore answers to their questions.

The development of repositories is underway. Once it becomes easy to publish documents and maintain individual repositories, issues of navigation and analysis outweigh those of access and organization. There are several efforts partially supported by the HORIZON project that are aimed at scalable access, organization, and analysis.

One key issue in providing a scalable and distributed repository environment is the naming of WWW documents. After investigating several strategies, the Corporation for National Research Initiatives' (CNRI) "Handle" server is being adopted. A handle or uniform resource name (URN) is a unique, location-independent, and permanent document identifier. Documents are referred to by URNs, not uniform resource locators (URLs) as currently done. When the location of the document is changed, the embedded links (the URNs) that point to that document do not break. Rather, the document's URL is changed in the URN database. These URNs are intended to be used with the WWW in the short term and with larger non-WWW based systems in the future.

The handle management system includes a handle generator and a handle server. The server consists of a caching server and a global set of base handle servers and includes secure tools for administration of handles. The server is designed to resolve very large numbers of handles rapidly, and to scale without limit. URNs will be deployed in several testbeds to investigate their reliability and eventually the CNRI "global" handle will be employed in the

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Readers are invited to contribute articles or information regarding published works, awards, announcements (research, opportunity, or CANs), or calendar events for publication. All submittals, changes of address, or questions or comments on content should be sent to the editor, Sandi Beck, Telos Information Systems, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA, 91109; 818-393-3768; sandi_beck@iplmail.jpl.nasa.gov

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NCSA production environment for use by the general community.

Another issue in the development of repositories is the storage of secure objects that include documents, data, and code for manipulating them. Staff at NCSA, CNRI, and Cornell are designing and implementing a secure object repository infrastructure that will ensure contractual “Terms and Conditions”, including copyrights and payment. In addition, a prototype certificate authority will be implemented to provide needed authentication for users of the repository.

The Interspace is a future system that seeks to unify disparate distributed information resources in one coherent model (http://csl.ncsa.uiuc.edu/IS.html). The Interspace as an entity is a collection of interlinked information spaces where each component space encodes the knowledge of a community or a subject domain. An information space is a collection of interlinked objects. With the Interspace, you can cross-correlate information in multiple ways from multiple sources. Standard services include inter-object linking, remote execution, object caching, and support for compound objects (usually referred to as compound documents).

Ultimately, the Interspace system is an attempt to represent all types of data/objects in one flexible, cohesive, and scalable system. Navigating information paths and grouping related items is a fundamental operation in the Interspace. Semantic retrieval and community classification, with interactive support for vocabulary switching across domains and subject indexing for amateur classifiers, is provided.

The architecture of the Interspace has been defined and implementation of a prototype is now underway. The Interspace architecture is an application environment for interconnecting spaces for manipulating information, much as the Internet is a protocol environment for interconnecting networks for transmitting data. Effectively implementing this environment will require building future operating systems that incorporate both computer science research on distributed objects and information science research on semantic retrieval.

The prototype system being implemented will be tested with NASA datasets (Earth & space science images). It will also be linked to the National Science Foundation, Advanced Research Projects Agency, and the NASA-funded Digital Library Initiative testbed at the University of Illinois that is focusing on engineering and science journals (http://www.grainger. uiuc.edu/dli/ and Schatz et al., 1996).

The testbed servers

There are two testbed servers for the HORIZON project: one for astronomy images (ADIL) and one for atmospheric and environmental science information (TDP). ADIL is being built for use by astronomers and the public to access astronomy images. These two user communities will use their own appropriately designed HTML interface for locating and displaying the image data. The public will use more popular terminology to locate historical and current images (to be implemented), while an astronomer will browse the library “card” index, searching on object names, regions of the sky, object types (galaxies, molecular clouds, etc.), type of data (continuum map, spectral-line datacube, etc.), frequency and/or spectral-line transition, etc. (see http://monet.ncsa.uiuc.edu). Both interfaces are provided through a network browser (e.g., NCSA Mosaic or Netscape) that queries a relational database. When a set of files of interest has been located, a postage stamp representation of the image or a short movie of a data cube is displayed. The full image can then be acquired by simply clicking on the data transfer button.

There are several ways in which the digital library will be of benefit. Observers planning a project will have access to work previously carried out on the same object, perhaps at different frequencies or in different spectral lines. Visualization and analysis tools can be used to re-bin and re-register image data sets, so astronomers will be able to use the archive for easy and straightforward overlay of existing images for comparison and analysis. Full resolution color images can then be acquired with useful metadata provided for astronomers and interpreted for the public.

ADIL has now been linked to the NASA Astrophysical Data Systems (ADS) (http://adswww.harvard.edu/) Abstract Service. Image Preview pages in the library contain direct links to related abstracts in the ADS abstract database. Similarly, ADS users who locate abstracts related to images in the library may now access the images from the ADS interface. Currently work is underway to combine ADS abstract searches with ADIL searches in order to improve the location of images.

AipsView is being developed to aid in visualization of ADIL images (http://monet.ncsa.uiuc.edu/AipsView/av.html). Currently, it is a tool for two-dimensional visualization and relies on Motif and Xlib for its user interface and drawing capabilities. A companion tool for three-dimensional visualization, AipsView3, requires OpenInventor, and is in the early stages of development. AipsView has an easy to use graphical user interface and can read FITS image files and single SDS files written in HDF format. Images are displayed in 2D including orthogonal slices from 3D data cubes. Image scaling, animation, simultaneous display of multiple images, synchronized animated display through multiple data cubes, and other image standard functionality is provided. AipsView requires a reasonably sized machine, with reasonable amounts of memory and swap space. It has been tested on Sun (SunOS and Solaris), SGI, HP, IBM RS6000, and DEC Alpha, and as a client of a MacExodus server.

The Daily Planet™ (http://www.atmos.uiuc.edu/) is a WWW-based environmental information server developed in the Department of Atmospheric Sciences that provides access to meteorological, climatological, hydrological, and EOS databases, multimedia educational modules, distributed archives of data sets, both real-time and retrospective, and other Internet-based resources. It has a large national user base and experiences up to 80,000-180,000 requests per day. It is used for education at all levels, including teachers and students associated with the CoVis Project (http://www.covis.nwu.edu/).

The goal of CoVis is to bring together scientists, teachers, and high school students through the use of high-speed computing and communication technologies to carry out projects as part of a high school student's learning process. Through video-teleconferences, students at their schools can interact with mentors at universities and can have access to daily and historical weather information over the Internet. Instructional modules have been and are being developed with text and graphics augmented by sound, animation, and video to aid the student in learning about atmospheric science.

Recently through CoVis and HORIZON funding, the Weather Visualizer was announced (Ramamurthy et al., 1996). It allows you to generate customized weather images "on the fly" from real-time weather data. This enables you to display only the information of interest. The introductory document of the Weather Visualizer consists of a graphical panel with six weather categories: Surface Observations, Upper Air Observations, Upper Air Soundings, Radar Summary, Satellite Imagery, and Forecast Images.

For each of these categories there is an HTML document that presents choices and solicits input as to which meteorological parameters to display. When selection of the parameters is completed, the form is processed on the server, resulting in the return of the image, plot, or textual data requested. Typical end products would be a map of US surface observations, radar echo summary, and frontal analysis superimposed on an infrared satellite image background; a table of forecast model output statistics; or a Stuve thermodynamic diagram.

An additional feature is the generous use of "helper sections" that employ the hypertext functionality of HTML to explain what the various parameters and map items mean and how the items or products are typically used in interpreting the data. For example, context sensitive help and explanations make complex imagery understandable by novices. The range of analysis options available will make this tool valuable to advanced users as well.

Increasing use of this software over the WWW creates an important testbed environment for the HORIZON project. The server acts as both a document source and as a compute engine creating the weather displays. This places a significant new burden on the server. In order to explore the impact of increased usage, five new HP715/100 workstations and 45 Gbytes of disk will be coupled with the current HP715/75 and HP720 server and preprocessed product generation machines. An additional new HP715/64 workstation will act as a router to distribute incoming requests between the machines.

For further information access the Horizon Project's WWW site at:

http://www.atmos.uiuc.edu/horizon/

The Net of the 21st century will have a very different character than at present. There will be billions of repositories, both large and small, maintained and indexed by many communities.

References

The following reference materials were used in the preparation of this article:

[1] M.K. Ramamurthy, R. B. Wilhelmson, J. G. Kemp, S. E. Hall, M. Sridhar, W. L. Chapman, B. Fishman, D. Gordin, R. Pea, and L. Gomez, 1996: *CoVis Geosciences Web Server: An internet-based resource for the K-12 Community*, Preprints, Fourth Symposium on Education, Atlanta, Georgia, AMS.

[2] M. K. Ramamurthy, R. B. Wilhelmson, R. D. Pea, L. M. Gomez, and D. C. Edelson, 1995: *CoVis: A National Science Education Collaboratory*, Fourth Symposium on Education, January 16-17, Dallas, Texas.

[3] B. Schatz, Mischo, T. Cole, J. Hardin, L. Jackson, A. Bishop, L. Star, P. Cochrane, and H. Chen, 1996: *Digital Library Infrastructure for a University Engineering Community: Towards Search in the Net via Structure and Semantics*, IEEE Computer special issue on Large-Scale Digital Libraries, 12pp. (to appear).

[4] D. P. Wojtowicz, and R. B. Wilhelmson, 1996, *The Interactive Image Markup Language (IIML) For Web Use*, Preprints, Twelfth International Conference on Interactive Information Processing Systems for Meteorology, Oceanography and Hydrology, Atlanta, Georgia, AMS.

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Calendar

MAY

20-24	Sixteenth Annual ESRI User Conference, Palm Springs, CA; 909-793-2853; Fax: 909-793-5953; ucregis@esri.com:
20-24	American Geophysical Union, Baltimore, MD; Karol Snyder; 202-469-6900; Fax: 202-328-0566
27-31	1996 International Geoscience and Remote Sensing Symposium, Lincoln, NE; 713-291-9222; Fax: 713-291-9224

JUNE

2-6	SIGCSE/SIGCU conference on Integrating Technology into Computer Science Education, Barcelona, Spain; Lillian Cassel; Villanova University; 610-519-7341; sigcse@vill.edu
24-27	2nd International Airborne Remote Sensing Conference and Exhibition, ERIM, San Francisco, CA; 313-994-1200 x3234; Fax: 313-994-5123

JULY

9-19	International Society for Photogrammetry and Remote Sensing, Vienna, Austria; Lawrence Fritz; 301-460-9046; Fax: 301-460-0021

AUGUST

4-9	SIGGRAPH'96, New Orleans, LA; Smith, Bucklin & Associates, Inc.; 312-644-6610; Fax: 312-321-6876; siggraph96@siggraph.org
18-23	Information Technology Conference, Seattle, WA; Graphic Communications Association; 703-519-8193; Fax: 703-548-2867; mle@gca.org

Supercomputing '95

New Directions, New Perceptions

Supercomputing (SC95), the eight annual conference and exhibition for high performance computing, hosted nearly 150 research and industry organizations at San Diego, California, this past December, with more than 5000 attendees. The latest progress in various fields of computational science (biochemistry, biology, engineering, fluid dynamics, ocean and atmospheric modeling, and physics) was presented.

The SC95 program, which covered a range of topics (data mining, performance, parallel technology, networking, and computer architectures) consisted of papers, panels, tutorials, workshops, computing center roundtables, poster competitions, the High Performance Computing (HPC) Challenge, and an exhibition arena. Over 70 technical papers were presented. Lead-in speakers, experts in their fields, moderated the panels sessions and workshops. Seventeen tutorials were offered on topics from evolutionary and genetic algorithms to World Wide Web (WWW) and HPC technologies for distance education. The HPC Challenge contest featured groups trying to outdo each other in commandeering the largest number of processors in the race toward achieving a teraflop in performance in the categories of Earth sciences, materials sciences, mathematics, microphysics, and molecular biology. The 161,000 square foot exhibition arena included a forum that featured noncommercial presentations on new research, applications, and services of interest to the High Performance Computing and Communication (HPCC) community. Most exhibits featured interactive and Web-based presentations.

Speakers' views

The conference hosted several invited speakers from universities, research institutions, and industry. The general theme among all of the speeches was that supercomputing is no longer performed only by scientists at large institutions; the performance and perception of high performance computing is changing. For example, in the keynote address, "And Now for Some *Really* Super computing", William Wulf, AT&T Professor of Engineering and Applied Science at the University of Virginia, talked about the impact of information technology. "It was not so long ago that supercomputing was essentially synonymous with high performance scientific computing, and all the emphasis was on high performance," Wulf said. "Increasingly, however, ...the emphasis on performance is being shared with graphics, networking, libraries, and web-browsing. Inevitably this trend will only increase."

Cherri Pancake of Oregon State University stated in her talk, "The Emperor Has No Clothes", " High performance computing has not delivered what it promised. Although capabilities continue to expand, high performance computing has not improved our productivity. It's time to acknowledge that high performance computing will never be mainstream unless we can make these machines usable."

In "Thriving on Information Anxiety: A Survival Guide to the Knowledge-value Revolution", Sam Falk Milosevich of Eli Lilly and Company suggested, "At the interface between the people with the problems and the platforms with the power, applications can be a point of significant competitive advantage in combatting information anxiety. ....Because high performance computing doesn't solve problems—high performance people do that—effective "carbon cycles" are as critical as efficient "silicon cycles" in the delivery of high performance computing solutions having unique knowledge value."

San Diego Supercomputer Center's John Donegan pointed out that many items used by the general public every day now contain computers—cash registers, hotel doors, and automobiles. In his speech, "How Many Miles per Gallon Does Your Computer Get?", he poses the thought, "...[this] is really a question of how the research in today's supercomputer centers will affect the products in our daily lives in a few years. This is a very different concept from one of building large machines and selling computer cycles to scientists."

> **At the interface between the people with the problems and the platforms with the power, applications can be a point of significant competitive advantage in combatting information anxiety.**

Information architecture

SC95's information architecture transmitted and delivered information to the conference attendees, providing a seamless networking infrastructure (SCinet'95) that integrated electronic audio/visual support with local and national networking. The SCinet'95 allowed researchers, exhibitors, and attendees access to other computers on the show floor and at their home institutions, using asynchronous transfer mode, FDDI, serial HIPPI, switched Ethernet, and shared Ethernet. SCinet'95 supported the Information Wide Area Year (I-WAY), an experimental, high performance network linking dozens of computers around the nation, advanced visualization environments, and national research networks. SCinet'95 also collaborated in the design of the on-site local experimental networks: the Wide Area Visualization Experimental (WAVE) network, the wireless local-area network that provided continuous Internet access and wireless systems, and video server technology that demonstrated real-time and stored video made available via the WAVE and I-WAY (parallel computers were used as video server engines to store and play back hundreds of hours of conference activity on demand).

The GII Testbed, which was created to accelerate development of teams and tools for the kinds of distributed computing necessary to meet Grand and National Challenges, showcased interactive 2D and 3D scientific visualization and virtual reality demonstrations, with simulation software remotely executing in the scientist's numerical laboratories. The results were then transmitted over high-speed networks to the convention center. The emphasis was on distributed, real-time, heterogeneous supercomputing, very large stores, remote instrumentation, and collaboration. Many applications had graphical results that were output to virtual reality and scientific visualization display technologies, such as the CAVE Automatic Virtual Environment (CAVE™), the ImmersaDesk™, and the NII/Wall. The CAVE and the ImmersaDesk each ran various applications for a limited number of hours each day.

The CAVE is a virtual reality theater; a multi-person, 10x1x9 foot room-sized, high-resolution 3D video and audio environment that was developed by the Electronic Visualization Laboratory (EVL) at the University of Illinois, Chicago. A 3D stereo effect is created by rear-projecting left-eye and right-eye images onto three walls and down onto the floor in rapid, alternating succession. These images may be viewed through LCD shutter glasses, whose lenses open and close in synchronization with the flashing images, or through head-mounted-display goggles. A tracking device attached to the goggles communicates the position and orientation of the viewer's head to the computer, which continuously updates the simulation, reflecting each new perspective. The viewer may navigate through the data, i.e., walk through a virtual thigh bone, or provide input using a 3D wand. Persons wearing the shutter glasses see 3D views from the perspective of the person being tracked.

The ImmersaDesk, also developed by the EVL, is a virtual prototyping device in a drafting table format. It is a scaled down version of the CAVE that brings 3D virtual environment technology into the office. The ImmersaDesk, although portable, is large enough to fill a person's field of view when seated in front of it. Images are viewed through shutter glasses.

The NII/Wall, developed by EVL, the National Center for Supercomputing Applications, and the University of Minnesota (with support from Silicon Graphics, Inc.), is a large-screen, high-resolution, stereo-projection display. Images appear on one plane and can be in stereo, as with the ImmersaDesk. The Advanced Research Projects Agency (ARPA) HPC Enterprise in Arlington, Virginia, served as a Washington DC area portal to the convention center. ARPA's CAVE was used for CAVE-to-CAVE and telepresence experiments between ARPA and SC95. Also, ARPA's large-screen projection display was part of the video-over-ATM experiment to broadcast key conference sessions.

The GII Testbed presented demonstrations in the categories of astronomy, astrophysics, atmospheric science, biochemistry-molecular biology-structural biology, biological and medical imaging, chemistry, distributed computing, Earth science, engineering, education, geometric modeling, mathematics, micro and macrophysics, neuroscience, performance analysis, plasma physics, teleoperations/telepresence, and visualization.

The education program

SC95's education program included a poster session, tutorials, a special teachers'/students' day, kindergarten through grade 12 (K-12) sessions, and graduate/undergraduate sessions, plus a special day for teachers and administrators that featured a higher level of direct involvement with High Performance Computing and Communication technology and applications. This program focused on high performance computing, computational science, information technology, and community networking. The poster session displayed posters on K-12 high performance computing programs. Six education papers were presented in the categories of K-12 curricula of the future and innovative educational issues. Daily panel topics ranged from trends in supercomputing for classroom use to community networking to electronic publishing. The organized "Education Days" included workshops on using the Internet and Web browsers for Teacher/Administrator Day; workshops on the internet, image processing, ray tracing, and computer animation for Teacher/Student Day; and hands-on sessions in visualization, computational science applications, Web information, collaboration sessions (CU-SeeME desktop videoconferencing and collage) and using tools, such as using hypertext markup language and Hot Java.

NASA's K-12 Internet Initiative presented a poster, "The Internet in the Classroom", and offered informational material on the various services available through the Information Infrastructure Technology and applications (IITA) Program. IITA K-12 activities are carried out at most NASA centers by organizing various interactive online projects that connect classrooms with ongoing science and engineering work, providing relevant content that enhance curriculums. Conference attendees were offered information about Spacelink (Marshall Space Flight Center), which houses a large collection of current and historical information about NASA's projects and missions, and educational programs, and Quest (Ames Research Center), which houses curriculum supplements for teachers, information about educational reform, and archives of interactive projects. Additionally, information on other NASA center activities was offered, including the Electronic Busing program (uses computer technology, the Internet, and the WWW to connect schools serving diverse student groups in widely separated school districts) and the Teachers' Access to the Internet, a training course for teachers, (Dryden Space Flight Center); the Earth and Environmental Science Teacher Ambassador Program, a computer, Internet, and Earth science training course for Maryland teachers and the Earth System Science Course ECOlogica, a student-constructed, computer-mediated Earth system science course that integrates NASA data and computational resources into high-school level curriculum (Goddard Space Flight Center); the Telescopes in Education program, which provides the tools to students to make hands-on discoveries in astronomy and astrophysics (Jet Propulsion Laboratory); the Internet Library Information Assembly Database, an in-development system that intelligently retrieves, processes, and transfers Internet resources to classrooms (Johnson Space Center); an affordable method of connecting a local area network to Internet services, currently being implemented by public school in the Virginia Tidewater area (developed by Langley Research Center); and a teacher training course on high performance technologies, where hands-on use of HPCC hardware and software is provided (Lewis Research Center).

The research exhibition

Highly interactive, working demonstrations of research projects were available on the exhibit floor in the research forum. SC95 attendees were able to meet with the project developers and discuss the demonstrations by various supercomputing centers, universities, NASA centers, and research laboratories and institutes from the US and other countries. To name just a few developers and their projects:

- The National Ocean Atmospheric Administration Forecast Systems demonstrated the use of distributed memory machines in real-time numerical weather prediction with a software toolbox that parallelizes numerical weather prediction models—realtime visualizations are produced as the forecasts are generated.
- The Scientific Computing Division of the National Center for Atmospheric Research (NCAR) developed a new highly refined chemical/transport model of the troposphere that simulates the 3D distribution of approximately 40 chemical species (including greenhouse gases) in the atmosphere.

- The California Institute of Technology's Center for Advanced Computing Research, in collaboration with Jet Propulsion Laboratory, exhibited various technological and scientific results obtained through the use of high performance machines and networks, presenting hands-on demonstrations of tools and environments.
- Ames Research Center demonstrated the Video on Demand system (see issue 37, 1995) and a visualization workbench.
- The National Science Foundation, The Advanced Research Project Agency, and NASA demonstrated their cooperative 3D project, a model, distributed by satellite, to improve atmospheric and marine forecasting and enhance research capacity.

Press room of the future

SC95 introduced the "Press Room of the Future", providing state-of-the-art press relations with the proceedings on CD-ROM, electronic media (rather than hard copy) press release and hand-outs, and a bank of PCs and Macs with various word processing applications, and Internet and email connections. A special press relations page, with an overview of the conference, was offered on the WWW. This Web page listed all exhibitors, provided a daily update of announcements, and linked to each participating exhibitor's home page, facilitating the research of background information.

Spacelink can be accessed using Gopher (spacelink.msfc.nasa.gov) or the Web (http://spacelink.msfc.nasa.gov). Quest can be accessed using Gopher (quest.arc.nasa.gov) or the Web (http://quest.arc.nasa.gov).

Analyzing Multispectral and Hyperspectral Image Data

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The use of multispectral image data has been a mainstay of land remote sensing since the 1960’s. Its use became especially widespread with the beginning of the Landsat series of satellites in 1972. The use of pattern recognition methods for analyzing such data has been the primary approach in programs where large land areas were involved. The method basically relies upon the analyst to define a set of land-cover classes that are of interest (and spectrally separable), and then to label representative examples of each of these classes in the dataset to be analyzed. These labeled samples are often called training samples. You can then apply one of a number of classification algorithms and implementations to assign every pixel in the data set to one of the defined classes, and either display the result as a thematic map or output tabular information on the extent of each class or both.

The analysis process

Besides naming the classes and labeling the training samples, there are a number of questions that must be addressed in the analysis process. For example, you must decide what features to use for the classification. This is especially important when there are more than a few spectral bands involved. Often you do not want to use all available bands, because the amount of computation increases rapidly as the number of bands used is increased. More importantly, you often can obtain higher accuracy if a number of bands or features less than the complete set is used. This is because, in remote sensing, it is usually the case that the number of training samples available by which to estimate the statistics of each class is limited. Now, as the number of features used goes up, you might reasonably expect the accuracy of classification to go up. However, with a fixed number of training samples, the precision by which the class statistics can be estimated goes down. At some point the added value of more features is overcome by the added error in estimation of the class statistics. This phenomenon is a limitation whether the classifier is a parametric or a non-parametric one, and whether implemented in the conventional fashion or as a neural network. Indeed, it become more severe in the non-parametric case.

One possibility for feature dimensionality reduction is feature selection, i.e., to select a subset of the available bands in some optimal way. Another possibility, referred to as feature extraction, is to form a linear combination of the original bands in an optimal way relative to the particular data set and classes at hand.

Approaching the problem

Many have tried to approach the problem of determining the class statistics without having to label training pixels. With this approach, you attempt to begin with spectra measured at a previous time; perhaps, for example, with a precision field spectrometer. To use this approach, you must reconcile the conditions under which the new data set was collected with those under which the field spectra were collected. This implies either adjusting the field spectra to those that would have been the case, if they had been collected at the same time and under the same circumstances as those of the new data set (or vice versa), or to adjust both to a common third standard by calibration.

Adjusting the spectra has proven very difficult to do with adequate precision. There are many variables in the scene that must be taken into account. Examples include the atmospheric transmission, the hemispheric sky illumination, path radiance, adjacency effects, the sun and view angles and non-lambertian reflectance effects, and the conditions of soil and plant moisture, etc. Further, as sensor signal-to-noise ratios have improved over the years, the precision to which these data adjustments must be made has steadily increased. Thus, the task of correctly making all of these adjustments has become intractable. Though attempting to achieve adequate precision for such data adjustments may be an important problem from a scientific standpoint, it is not likely ever to prove useful in practice except in cases of very separable classes. Its value lies primarily in the understanding of scene spectral responses and the sensitivity of scene variables affecting these spectral responses one gains in the process of studying it.

Though it may not at first seem so, the approach of labeling training samples within each data set to be analyzed remains the most tractable, especially for problems involving large areas. One characteristic of this approach, though, is that the part of the process involving defining the classes and labeling the training samples is not easy to learn. At this point in its development, the approach requires a thorough understanding of the characteristics of data in multidimensional space and its relationship to the scene and scene variables of interest. Thus it is still more of an art than a science at this time.

Substantial advances are also taking place in the engineering of sensor systems. Due primarily to advances in the engineering uses of solid state devices and materials, it has become possible to build imaging multispectral sensors capable of generating data in several hundred bands at one time, and at the same time, doing so with a substantial increase in signal-to-noise ratio over those previously common. Such data is now often referred to a hyperspectral data.

An increase in the number of spectral bands by more than an order of magnitude, with a substantial increase in signal-to-noise ratio means that the potential information content contained in such data should be much higher than before. However, such an augmentation also means that a fundamental re-look at the analysis process is required, because it is not likely that simple extensions of previous methods will achieve the full potential of such data.

The research effort

It was to address this problem that a research effort by the authors was begun several years ago with the aid of NASA funding. The problem required returning again to a fundamental look at data in high dimensional spaces and coming to understand just what high-dimensional spaces are like. It was also recognized that the algorithms that were going to be needed for such data are likely to be complex and not easy to reproduce in multiple laboratories over the world so that researchers could try them out and begin to learn them. Thus it was decided at the outset to approach this problem of technology transfer in a novel way.

What was done was to build a basic multispectral data analysis software system. This analysis system, because of its primary purpose, was to have the characteristics of being easy to learn and easy to use, even for the infrequent user, and it should be implemented on a hardware platform that cost no more than $5000, so as to be affordable by anyone. At that time the Apple Macintosh platform was selected as best meeting these criteria, and though the processing power available then on this platform was limited, it seemed clear that it would grow very rapidly.

The software system would be made available to anyone at no cost, thus providing the minimum of barriers to anyone wishing to try it. Then, as the research proceeded and new algorithms well suited to the new hyperspectral data were discovered, they would be incorporated into the analysis system. Upgrades to the software would be issued, again to anyone requesting it, at no cost. In this way the time from creation of the needed new algorithms to their productive use could be reduced to a minimum.

Both the research effort and the method of technology transfer appear to have been successful so far. There are now more than 500 registered recipients of the analysis system, named MultiSpec©. They are located around the world in universities, government offices, commercial concerns, and other organizations. Indeed, as an indication of the success in achieving the ease-of-use goal, the system has been requested for several hundred secondary schools and has been adopted by the Global Learning Observations to Benefit the Environment (GLOBE), a program of NASA, the National Oceanic and Atmospheric Administration, and the National Science Foundation (see http://www.globe.gov/ on the World Wide Web (WWW)). As a result, it is being made available to the 1900 secondary schools participating in the Globe program.

Availability

MultiSpec© has been licensed for distribution via several CD-ROM collections of software and data, including one by the Goddard Space Flight Center Distributed Active Archive Center. The standard version is available for PowerPC Macintoshes in native mode and for 680x0-based Mac's with a math coprocessor. A special version is available for 680x0 Mac's that do not have a math coprocessor. Based on funding from the GLOBE program, a version for Windows-based PC is now under construction. There are no plans at present to produce a UNIX version, although the standard Mac version may be run on UNIX machines that have the Macintosh Application Environment package installed.

MultiSpec© is now made available via the WWW, along with documentation for the system, demonstration analysis examples including the data used, and a bibliography of papers resulting from the research effort. A few key papers of these may also be downloaded in their complete form. Access this software on the WWW or by email at, respectively:

http://dynamo.ecn.purdue.edu/~biehl/MultiSpec/

landgreb@ecn.purdue.edu

On The Web

The *Science Information Systems Newsletter* is now available on the Internet at:

http://techinfo.jpl.nasa.gov/jpltrs/sisn/sisn.html

Please send comments or suggestions to Sandi Beck at:

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Introducing The SPICE "Database Kernel"

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The SPICE information system is a means for collecting, archiving, and accessing ancillary observation geometry data files—often called kernels—and related tools used in the planning and interpretation of science instrument observations from planetary spacecraft. The E-kernel subsystem is that portion of SPICE that deals with mission Events data. Scientists expect to use these events data to help better understand the exact performance of science instruments, the host spacecraft, and the mission's ground data system. The E-kernel would help answer questions such as:
"What operating mode was being used when..."
"Did thus-and-so happen, and when?"
"Did something out of the ordinary happen during ..."

The key requirements placed on the E-kernel subsystem were that it must be flexible, to hold a wide assortment of data constructs; queryable, to find information of possible interest; portable, to work on multiple platforms; and free to the user (as is the remainder of the SPICE system). These specifications pointed to a database-like product. The initial implementation, completed for use by NASA's Mars Observer mission, indeed had the flavor of a very simple database, but was clearly a custom product suitable only for the Navigation Ancillary Information Facility (NAIF) Group's imagined E-kernel functions. The premature loss of Mars Observer offered additional time to scrub the E-kernel design. The evolving sense of E-kernel requirements combined with NAIF ideology embracing robust, extensible solutions led to a decision to generalize the initial design to one providing substantial database functionality; hence, NAIF's so-called Database Kernel (DBK).

NAIF's intent with this design is to provide SPICE users a fundamental new kernel—the DBK—that will have numerous uses, including serving as the basis for the Events kernel. In this article the principal features of the DBK are outlined and its use in solving several information management problems is described.

DBK design

The DBK subsystem is designed to accommodate data that are organized according to the relational model. Mathematically, this means the data may be represented as a collection of relations, where each relation is a set of tables of items. Informally, you may think of the data as represented by a collection of one or more two-dimensional tables, where each table has a set of columns, and each column in a given table contains the same number of rows. Each column has several attributes, They are:

- Data type—each datum within a column is of the same type. Allowed data types in the DBK subsystem are: CHARACTER, INTEGER, DOUBLE PRECISION, and TIME. Most commercial systems support character strings, numbers, and dates.
- Columns containing CHARACTER values have an additional attribute: string length. The length may be fixed or variable.
- Whether null values are permitted in the column. Null values allow a database to indicate that a value is absent.
- Whether the column is indexed. Columns with indexes normally can be searched much more quickly than non-indexed columns.
- A column name. The name is used to reference the column when the database is queried.

In many database systems, each datum within a column (or "column entry") is a scalar. The DBK subsystem allows column entries to be array-valued. The arrays may have fixed or variable dimension. Array-valued columns are not fully supported in that their components may not be referenced in query constraints. Array-valued columns allow incorporation of very large data, such as lengthy text entries, into the DBK format.

The DBK query language

A database query language is a mechanism for asking questions about the contents of a database. A query generally selects from one or more tables in the database data that satisfy specified constraints. The result of a query is itself a logical table with columns and rows defined by the query. The general syntactic form of a query is:

<SELECT clause> <FROM clause> <WHERE clause> <ORDER-BY clause>

where the SELECT clause specifies a set of columns whose contents are to be used to form the query's result. The FROM clause specifies the tables containing the columns listed in the SELECT clause. The WHERE clause specifies constraints on the rows that will appear in the query's result. The ORDER-BY clause is used to control the ordering of the rows in the result. The WHERE and ORDER-BY clauses are optional. The result of a query is a table whose columns are specified by the SELECT clause, and whose rows are those from the tables specified by the FROM clause that satisfy the constraints listed in the WHERE clause. An example of a query and the result is shown in the section below describing the Clementine Image Catalog.

The use of multiple tables in the FROM clause is called a "join," since the rows of the query's result will be formed by joining parts of rows of the tables in the FROM clause. A mathematically precise description of a join is: a table whose columns are specified by the SELECT clause, and whose rows are those belonging to the Cartesian product of the rows of the joined tables and satisfying all of the constraints of the WHERE clause. For joins between two tables, constraints are frequently specified to ensure that rows in the result are limited to those for which the values in a specified column in the first table are equal to values in a specified column in the second table. This is called an "equi-join."

The currently supported features of the SPICE DBK query language are summarized below. This language is closely related to SQL; any SQL construct appearing in the DBK language has the same meaning as in other SQL implementations, if a consensus on the meaning exists.

- Relational expressions in the WHERE clause: the relational operators EQ, NE, LE, LT, GE, GT, BETWEEN, NOT BETWEEN, LIKE, NOT LIKE, IS NULL, IS NOT NULL, =, <, <=, >, >=, <>, != are all supported. Relational expressions may be combined using parentheses and the AND, OR, and NOT logical operators. The LIKE and NOT LIKE operators do a case-insensitive pattern match that supports wild string and wild character symbols.
- Joins: up to ten tables may be referenced in a join query. Equi-join, non-equi-join, and null join constraints are permitted. Table aliases are supported.
- Literal strings: strings may be quoted with single or double quote characters.
- Time values: in queries, times may be represented in various time systems and formats, including ISO formats and spacecraft clock systems. Calendar dates are considered to be UTC times. This is an extension relative to most SQL implementations, which don't support the concept of different "time systems."
- Ordering: Up to 10 order-by columns may be listed. Each column's effect on the ordering may be modified by use of the ASC ("ascending") or DESC ("descending") keywords.
- With the exception of literal strings, the language is case-insensitive.

DBK files

DBK files are Fortran binary, direct access files. Since DBKs normally contain numeric data, they may not be ported directly between computer systems that have incompatible numeric representations. To enable porting, the NAIF Toolkit provides utility programs to convert binary DBKs to a portable, ASCII "transfer" format and to convert transfer format DBKs back to binary DBKs. The process is analogous to that used for porting binary SPICE SPK, CK, and PCK files.

The DBK design provides an annotation capability: each DBK contains a data structure called the "comment area". The comment area is completely distinct from the data contained in the DBK's tables. The comment area may contain an unlimited number of lines of 80-column ASCII text. Typically, the comment area is used to provide labels or other descriptive information that allows users to identify the file and determine its suitability for their intended use. The NAIF Toolkit contains a utility that enables users to append, read, and delete comments in the DBK comment area.

Each DBK can contain multiple tables and a table can be spread across multiple files. To assist in creating and partitioning very large DBKs, the contents of a table are organized as one or more distinct portions called "segments". The partitioning of tables into segments is determined by a DBK's creator. The subsystem imposes no limit on how many records may be in one segment. There is a (large) limit on the total number of segments that can be simultaneously considered by the DBK query software.

DBK programs

The principal program supporting the DBK subsystem is the browsing and report-generating program named INSPEKT. INSPEKT enables users to interactively query DBKs and display the results in an extensive variety of user-customizable formats. INSPEKT uses the DBK query language described earlier. INSPEKT has a command-line interface, and produces terminal-window style ASCII output. Construction of a GUI version is planned. INSPEKT has a number of effort-saving features. They are:

- There is a symbol definition capability that enables users to create short abbreviations for complex language constructs. Symbols can be defined so as to prompt the user for inputs.
- INSPEKT has an extensive, hyper-text style on-line help facility, and also has a detailed user's guide available as a paper document.
- INSPEKT automatically creates a log file recording the commands typed in during each program run.
- INSPEKT can present summaries of DBK schemas and display the contents of a DBK's comment area.
- INSPEKT allows users to recall, edit, and redo previously issued commands.
- INSPEKT can accept inputs from command files.
- INSPEKT can save query results to output files.

INSPEKT runs on VAX/VMS, DEC Alpha/Open VMS, Sun/SunOS, Sun/Solaris, HP, I-486PC/Lahey Fortran, I-486PC/Microsoft Powerstation Fortran, NeXT, and Silicon Graphics systems.

In addition to INSPEKT, several utility programs support the DBK subsystem. Binary/transfer format conversion is carried out by the menu-driven program SPACIT, or by the pair of command-line programs TOBIN and TOXFR. The latter are readily used within scripts. Comment area access (read, write, delete) is provided by the program COMMNT.

Application programming interface

All DBK read and write access methods are provided by NAIF Toolkit subroutines. The DBK application programming interface enables you to create new DBKs, update portions of existing DBK, read selected portions of DBKs, and query a selection of one or more DBKs and fetch the results of the query. Because the query and fetch interface is provided by the NAIF Toolkit, any query operation that can be performed by INSPEKT can be performed by a user's application program.

As is the case for the rest of the NAIF Toolkit, the DBK access software is written in portable, ANSI standard Fortran 77. The "plain-vanilla" Fortran implementation of the DBK subsystem enables it to be integrated easily into users' Fortran applications. Integration into applications built in C is not difficult. The NAIF Group may soon provide C "wrappers" for those DBK and other SPICELIB routines most frequently used by customers) Because the DBK software is portable to any system on which the NAIF Toolkit is supported, DBK applications can be readily ported between systems having different hardware architectures and operating systems, such as PCs and UNIX workstations.

Future development

There are some useful features provided by commercial relational database systems that are not provided in this version of the DBK subsystem. Future Toolkit releases are expected to include DBK enhancements. Planned upgrades include:

- acceptance of intrinsic functions (COUNT, MIN, MAX, SUM, AVG) in the query language
- acceptance of the SELECT * syntax
- support of the SELECT DISTINCT operation
- support of the GROUP BY and HAVING operators
- an interrupt ("Control C") capability in INSPEKT

- support of interactive writing and updating in INSPEKT or a similar program
- a GUI version of INSPEKT
- an import utility

Usage example

An example of use of the DBK subsystem to implement a simple but large database is found in the SPICE Clementine Image Catalog, consisting of about 1.8 million records—one for each image. Each image record contains 30 data items, most of which are indexed to improve query performance. NAIF used a DBK to keep track of these images and associate images with corresponding geometric data. Several of the Clementine experimenters used this catalog to identify images of interest to their data analysts. The catalog consists of the single table "CLEM_CAT." The names of the columns in the CLEM_CAT table are shown below, along with the columns' data types and indications of which columns are indexed.

<u>Column</u> : <u>Description</u>
CLEM_CAT.ALTITUDE: DOUBLE PRECISION (Indexed)
CLEM_CAT.CAMERA : CHARACTER*(6) (Indexed)
CLEM_CAT.COMP : DOUBLE PRECISION (Indexed)
CLEM_CAT.DEC : DOUBLE PRECISION (Indexed)
CLEM_CAT.DNMAX : INTEGER (Indexed)
CLEM_CAT.DNMEAN : DOUBLE PRECISION (Indexed)
CLEM_CAT.DNMIN : INTEGER (Indexed)
CLEM_CAT.DNSD : DOUBLE PRECISION
CLEM_CAT.EMISSION : DOUBLE PRECISION (Indexed)
CLEM_CAT.EXPOSURE : DOUBLE PRECISION (Indexed)
CLEM_CAT.FILE : CHARACTER*(12) (Indexed)
CLEM_CAT.FILTER : CHARACTER*(1) (Indexed)
CLEM_CAT.FRAME : INTEGER (Indexed)
CLEM_CAT.GAIN : CHARACTER*(3)
CLEM_CAT.INCIDENCE : DOUBLE PRECISION (Indexed)
CLEM_CAT.INCIDENCE_2 : DOUBLE PRECISION
CLEM_CAT.LAT : DOUBLE PRECISION (Indexed)
CLEM_CAT.LON : DOUBLE PRECISION (Indexed)
CLEM_CAT.OFFSET : CHARACTER*(3)
CLEM_CAT.OLD_FILE : CHARACTER*(12) (Indexed)
CLEM_CAT.PASS : CHARACTER*(8) (Indexed)
CLEM_CAT.PHASE : DOUBLE PRECISION (Indexed)
CLEM_CAT.PHASE_2 : DOUBLE PRECISION
CLEM_CAT.RA : DOUBLE PRECISION (Indexed)
CLEM_CAT.REV : INTEGER (Indexed)
CLEM_CAT.SC_LAT : DOUBLE PRECISION
CLEM_CAT.SC_LON : DOUBLE PRECISION
CLEM_CAT.SOURCE_2 : CHARACTER*(5)
CLEM_CAT.TARGET : CHARACTER*(5) (Indexed)
CLEM_CAT.TIME : TIME (Indexed)

Next is a sample query that illustrates use of some DBK operators, and the output INSPEKT generated in response to this query. The query is entered on multiple lines and is terminated by a semicolon.

```
INSPEKT> select time, camera, lat, lon, phase
from clem_cat, where lat between -12 and -13,
and lon between 160 and 162, and ( ( camera =
'UVVIS' ) or ( camera = 'LWIR' ) ) order by
camera, time;
```

The output identifies the times, camera boresight intercept locations, and phase angles at the intercepts, of all of the images taken by the UVVIS and LWIR cameras, where the boresight intercepts are constrained to lie in the latitude range -13:-12 and the longitude range 160:162.

Additional applications

The DBK could be used to construct a database for SPICE ephemeris files (SPK files). The database would keep track of what files exist, for which bodies ephemeris data is available, when and to whom the files have been delivered, and the names, addresses, and phone numbers of the customers. This schema requires four separate tables, one for each category of data. Another DBK use, actually implemented by NAIF, is a queryable star catalog. In this example data from a standard catalog, such as SAO or PPM, is imported into a DBK. A custom NAIF Toolkit subroutine is provided to allow easy selection of stars within a specified RA/DEC range that also meet specified brightness and spectral criteria. Data for those stars matching all the selection criteria are output through the subroutine interface to the user's application program. The catalog could also be searched using INSPEKT, yielding a screen display and optional text file.

A final example, illustrating integration of DBK with other SPICE elements, comes from the Cassini mission planning world. In this case one SPICE-based program calculates a wide assortment of orbit geometry characteristics, such as time, altitude and spacecraft ground track (LAT/LON) as the Cassini spacecraft flies by Saturn's satellites.

INSPEKT Report

TIME	CAMERA	LAT	LON	PHASE
1994 MAR 14 20:38:00	LWIR	-12.9500	160.5100	17.1700
1994 MAR 14 20:38:03	LWIR	-12.8100	160.5100	17.0400
1994 MAR 14 20:38:06	LWIR	-12.6700	160.5100	16.9100
1994 MAR 14 20:38:09	LWIR	-12.5300	160.5100	16.7900
1994 MAR 14 20:38:12	LWIR	-12.3900	160.5100	16.6800
1994 MAR 14 20:38:15	LWIR	-12.2500	160.5100	16.5700
1994 MAR 14 20:38:18	LWIR	-12.1100	160.5100	16.4600
1994 APR 11 07:54:11	LWIR	-12.9100	161.8700	20.0600
1994 APR 11 07:54:16	LWIR	-12.7200	161.8700	19.9400
1994 APR 11 07:54:21	LWIR	-12.5300	161.8700	19.8100
1994 APR 11 07:54:25	LWIR	-12.3400	161.8700	19.6800
1994 APR 11 07:54:30	LWIR	-12.1500	161.8700	19.5700
1994 MAR 14 20:38:09	UVVIS	-12.5200	160.5200	16.7500
1994 MAR 14 20:38:09	UVVIS	-12.5200	160.5200	16.7500
1994 MAR 14 20:38:10	UVVIS	-12.4900	160.5200	16.7300
1994 MAR 14 20:38:10	UVVIS	-12.4900	160.5200	16.7300
1994 MAR 14 20:38:11	UVVIS	-12.4500	160.5200	16.7000
1994 MAR 14 20:38:11	UVVIS	-12.4500	160.5200	16.7000
1994 MAR 14 20:38:11	UVVIS	-12.4200	160.5200	16.6800
1994 MAR 14 20:38:11	UVVIS	-12.4100	160.5200	16.6700
1994 MAR 14 20:38:12	UVVIS	-12.3800	160.5200	16.6500
1994 MAR 14 20:38:12	UVVIS	-12.3800	160.5200	16.6400
1994 APR 11 07:54:12	UVVIS	-12.9000	161.8800	20.0600
1994 APR 11 07:54:12	UVVIS	-12.9000	161.8800	20.0600
1994 APR 11 07:54:13	UVVIS	-12.8700	161.8800	20.0400
1994 APR 11 07:54:13	UVVIS	-12.8600	161.8800	20.0300
1994 APR 11 07:54:14	UVVIS	-12.8100	161.8800	20.0000
1994 APR 11 07:54:14	UVVIS	-12.8000	161.8800	20.0000
1994 APR 11 07:54:15	UVVIS	-12.7700	161.8800	19.9800
1994 APR 11 07:54:15	UVVIS	-12.7600	161.8800	19.9800
1994 APR 11 07:54:16	UVVIS	-12.7100	161.8800	19.9500
1994 APR 11 07:54:17	UVVIS	-12.7000	161.8800	19.9400

All of these geometric conditions are stored in a DBK. Subsequently, any scientist can use INSPEKT to query this database to search for times when observation geometry would satisfy particular science experiment objectives. If the appropriate observation geometry doesn't occur the scientist can advise the project of changes needed to meet the experiment objectives.

Conclusions

The SPICE DBK subsystem provides a portable, relational database capability at no added cost to NAIF Toolkit users. This capability may be more than adequate for many database applications, especially those involving a single user or multiple users requiring only read access to their database. The subsystem supports both interactive and API database access and is designed for easy integration into users' applications.

For further information about the NAIF Toolkit DBK contact the author at:

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Creating a New Web Coastal Zone Color Scanner Browser

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NASA's Coastal Zone Color Scanner (CZCS), designed specifically to detect small changes in ocean color, acquired nearly 68,000 ocean color images aboard the Nimbus-7 satellite during its 7-1/2 year operational lifetime from November 2, 1978, through June 22, 1986. Of these files, approximately 60,000 scenes were further processed and stored onto optical platters by the Laboratory for Hydrophysical Processes. These data have been transferred to the Goddard Space Flight Center (GSFC) Distributed Active Archive Center (DAAC), which fully supports their storage and distribution.

Ocean color data are used by scientists to derive estimates of phytoplankton abundance and primary productivity and to characterize global and regional physical oceanographic phenomena. In most cases, it is necessary for the researcher to be able to visualize individual ocean color data files to determine if they are suitable for their specific research application before ordering data.

The original browser

To address this need for visualization, GSFC created a CZCS browser in the late 1980's that allowed easy searching and viewing of all 59,337 archived individual two minute CZCS scenes. That implementation displayed analog images stored on eight inch video discs on a television screen using a video disc player. The search software, ported to VAX, Macintosh, and PC, was widely distributed and was used with or without the visualization equipment. Using the browser, CZCS data orders could be generated by researchers and sent via electronic mail to Goddard where they were filled. The logic tree of the browser was self-explanatory, robust, and very easy to navigate, even for novice users.

While providing quick and easy visualization of CZCS data, the browser depended on the availability of the video disc players. From the start, the high cost of these players greatly limited the number of researchers who could gain access, and only 35 remote browse facilities with full visualization were set up around the world. With time this equipment became obsolete and very difficult to find and maintain. When the GSFC DAAC assumed all responsibility for archiving and distributing CZCS data in early 1995, the players had long been discontinued by their manufacturer, making it impossible to set up any additional browse facilities for new customers. In addition, due to lack of support from the manufacturer, the players at many of the existing facilities were no longer operational.

The inability to visualize CZCS data created a fantastic barrier to the use of CZCS data by the majority of potential new customers and was greatly inhibiting the use of these data by the established ocean color research community. CZCS requests were reduced to a trickle from the few remaining functional browse facilities. New customers were not ordering the data at all. In mid-1995, the GSFC DAAC Ocean Color Data Support Team decided a new browser was critical to removing these barriers, opening the data set to a broader market, and recouping NASA's investment in the scientific value of the CZCS data set.

After numerous discussions with users of these data and SeaWiFS, the follow-on project to CZCS, it was decided to 1) retain the query logic of the original browser, 2) provide a World Wide Web (WWW) based interface to both minimize the developer's efforts and enhance customer utility, 3) port the software to several platforms including PC and Macintosh, 4) publish it on CD-ROM, and 5) distribute it widely. The initial release, whose development is described in this article, would run on DAAC computers and would be made available via the DAAC Home Page. In this way it would serve as a testbed for customer evaluation and modification before the CD-ROM version was produced. Putting the browser on the Web and providing it in CD-ROM format for desktop computers would give researchers and educators unprecedented, practically universal access to this data set.

After a cost analysis and in-depth discussions with the author of the original browser software, Norman Kuring, it was decided to create new code rather than modify the existing version. After several weeks of discussion and debate, our new browser design emerged. Based on the logic of the old browser's search engine, it would use new server side CGI bin scripts, lookup tables, and hierarchical data format (HDF) browse images, and be presented in a WWW user interface.

The new and revised features

The first task was to write the search and order engine. The WWW CZCS Browser engine uses the same logic as the original browser and is based on three simple lookup tables for latitude, longitude, and date of data file acquisition. Each individual two minute CZCS data file in the archive is given an index number that maps directly to the lookup tables and corresponding browse files. In the latitude and longitude lookup tables, all the indices of the files are stored in five degree spatial bins. When spatial and time ranges of interest are entered, the software first finds all files that fall into the five degree latitude bins specified and then flags those files. This is repeated for the longitude and date. The three lists of flagged files are then compared to find those files common to all three lists. These files are then used to generate the final list of "hits"; all unique files that satisfy the user's search criteria exclusively.

The browser engine is written in PERL, a more natural language for hypertext markup language (HTML) programming and more robust for string manipulation. The PERL program creates HTML documents on the fly, reading different user input parameters. Depending on the input, the program executes commands such as "display the image" or "view the previous or next image in the search result list." An order file is generated for insertion into the DAAC's order processing system. This engine can quickly and accurately search the entire CZCS data base, returning a list of all 59,337 Level 2 files in the archive in approximately five seconds, including transfer time back and forth over the network.

The next task was to design a user friendly interface for entering spatial and temporal ranges. The goal was to allow you to draw a box around an area or enter the specific coordinates to specify spatial areas of interest. An application was found on the TRMM Science Data Information System (TSDIS) home page that would meet this need, with minor modifications.

TSDIS offered this software and, with their assistance, the code was modified to support CZCS by inserting a global map and changing the default date ranges. The CGI bin scripts of the Browser search engine were then modified to accept input from this "Map" page and to provide output to a future "Results" page, which lists the files satisfying the search criteria.

The decision had been made to create a new HDF version of the CZCS Level 2 data set and to also create corresponding HDF browse images at the same time. Unfortunately, most WWW users do not have HDF visualization software installed on their machines and viewing the files would be an unacceptable roadblock. Therefore, it was necessary to find a way to allow all users to view the HDF browse files over the Web on all platforms.

The National Center for Supercomputing Applications (NCSA) was queried as to the viewing capabilities of all WWW browsers—to ensure that these new HDF browse files could be widely used on the Web. NCSA provided a prototype for a server-side HDF browsing program, "Scientific Browse-O-Rama," which opens up an HDF file and translates the information into a formatted HTML document, generating GIF representations of the HDF images on the fly. Thus any user accessing the application via the Web could view these HDF browse files from any platform. After installing the program the code was adapted to the CZCS Browser's specific needs and the output HTML code was modified to suit the CZCS data set. By using the NCSA visualization software, visualization of the HDF browse files was provided without creating an additional collection of GIF or TIFF images of the data.

Compatibility bonus

Several sample CZCS HDF browse files were then created and the Browse-O-Rama implementation was shown to SeaWiFS. It was learned that by renavigating the HDF CZCS browse files and providing a little extra information, the files were compatible with SeaWiFS's ocean color data processing package called SEADAS. This would allow the CZCS browse files to be directly compared with new SeaWiFS ocean color data browse files, facilitating long-term climateoceans studies and greatly increasing the utility of the CZCS data set to the ocean color research community.

Working with SeaWiFS SEADAS developers, several more sample files were produced , and then tested with SEADAS and Browse-O-Rama. These files were found to be compatible with both. Having reached agreement on the new HDF browse file format, a complete set of 59,337 new HDF CZCS Level 2 browse images were produced while creating the HDF version of the CZCS Level 2 data set.

Overcoming obstacles

Several obstacles were encountered in the production of the HDF CZCS files, the first of which was translating the files from their original "DSP" format into HDF. The DSP format was developed by researchers at the Rosenstiel School of Marine and Atmospheric Science (RSMAS) at the University of Miami and was unfamiliar to DAAC staff. The RSMAS sent copies of its documentation and routines, from which the original DSP format was learned, so the code could be cracked. The actual conversion to HDF was rather trivial after that.

Another obstacle was insufficient disk space for manipulating this volume of data. The uncompressed volume of the original Level 2 files was 8-9 GB, the HDF versions took up 14 GB, and the HDF browse images required an additional 4.6 GB. Because they had been pulled from the archive in numerous batches, the Level 2 files also had to be sorted into chronological order prior to conversion, requiring even more space. The timely arrival of 20 GB of new disk space was the key to success here.

Once the HDF files had been created, it was learned that 348 CZCS Level 2 files had been originally archived with horizontal or vertical axes reversed. This information was hidden deep inside the DSP documentation, and some programs were written to search the metadata extracting this information from the DSP headers. Once all the switched files were identified they were corrected and converted to HDF.

While the new HDF browse files were being generated, the Browse-O-Rama input and output was integrated into the rest of the browser code, linking the search engine with the browse images. The remaining pages of forms that would provide the necessary information for processing a request, such as data product and delivery method desired and customer shipping information, were created. Steps were taken to ensure that the format of the CZCS Browser's output order file would be compatible with the existing GSFC DAAC WWW order interface, allowing completed CZCS Browser order files to be inserted smoothly into the DAAC's Request table once a day, processed by the automated system, and shipped to the customer without manual intervention.

Finally all elements of the WWW CZCS Browser were integrated into one application allowing WWW browse and ordering of CZCS data for the first time. The CZCS Web Browser was promoted to the operational baseline in January 1996 where it is in use by customers today.

Using the browser

To try out the CZCS Browser, access the GSFC DAAC home page at:

http://daac.gsfc.nasa.gov/

Navigate to the Ocean Color branch. The Browser may be found in the Data Section of that branch under CZCS at:

http://daac.gsfc.nasa.gov/
CAMPAIGNDOCS/BRS_SRVR/
czcsbrs.html

CZCS data exist as individual, two minute scenes and as composites. There are very few composites, allowing these files to be accessed directly via ftp. However, to find the individual scenes that fit your search criteria, you must perform a search of the data base. Select the "Level 1, 1A, and 2 Individual Scenes" option on the first page to go to the "Map" page of the browser.

On the "Map" page, click on two corner points to draw a rectangle of your choice on the map of the world, thereby specifying your latitude and longitude coordinates with the mouse. Forms on the same page allow you to manually enter exact coordinates and to define the date range of interest. The page may be cleared at any time and new criteria entered. Select the “Start Search” button to send a query to the search engine. This will take you to the “Results” page where a list of files that fit the specified criteria is shown.

Clicking on any file name on the “Results” page sends you to the “Viewing” page where you will see a GIF image of the HDF browse file, its exact area of coverage on a global map, and some of the metadata associated with that file. You may save the GIF image to your own machine using the “save file” function of your browser. Click the “Other” button to add this file to your order and proceed to the next file in the list. Click on the file name at the top of the page to download the digital HDF browse file itself. Click on the question mark button to get help with using the browser.

Use the “Next File” and “Last File” buttons on the “Viewing” page to step through the Results list, viewing each file in turn and ordering those desired. You may also return to the “Results” page at any time and view any file on the list out of sequence. Click on the “New Search” button to abort this search and go back to the Map page to start a new search session. When you are satisfied that you have added all the files you want to your order, close the browse session by selecting the “Submit Order” button.

This sends you the “Order” page where you must specify the type of data desired. For CZCS, individual two minute scenes are available in three forms: Level 1 (raw radiances), Level 1a (reduced resolution raw radiances), or Level 3 (derived geophysical parameters, such as chlorophyll). On this page you must also specify the delivery method desired, whether tape or ftp. Select the “Submit Order” button again to go to the next and final “Shipping” page where you must enter your shipping information to complete the request. This completes the order file and the system shows you a “Confirmation” page verifying your request and giving you a unique request number for reference. Your data request enters the DAAC system that night at local midnight. It will then be processed and shipped to the address specified in your browse session.

Modifying the browser

With simple modifications the WWW CZCS browser can be adapted to support HDF browse image products from other data sets. Copies of the source code and the NCSA visualization software will be made freely available by the DAAC at:

karten@daac.gsfc.nasa.gov
or
li@daac.gsfc.nasa.gov

The GSFC DAAC Ocean Color Data Support Team is indebted to people of the SeaWiFS and TSDIS projects, NCSA, and the Rosenstiel School of Marine and Atmospheric Science, whose generous and expert assistance allowed us to complete the first phase of this project.

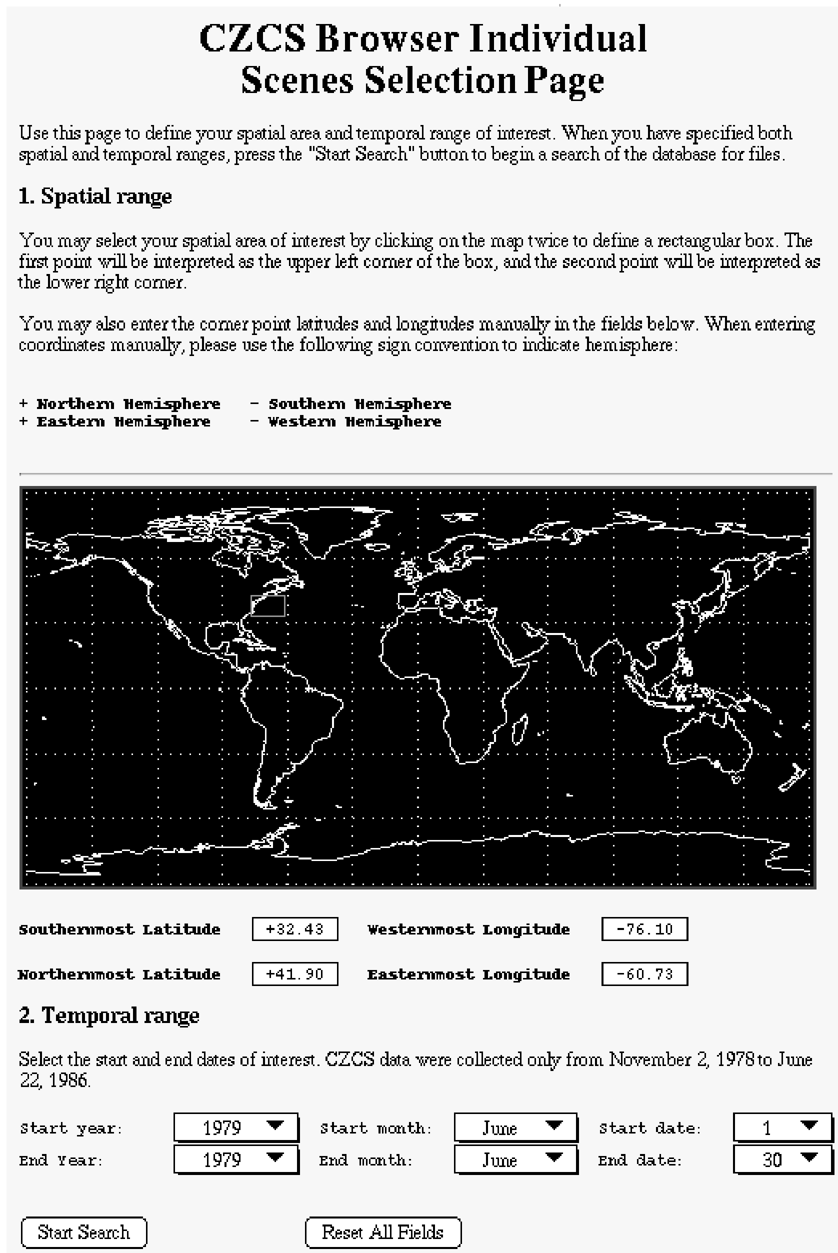

Figure 1. A clickable global map and forms on the Map page allow you to manually enter exact coordinates and define the date range of interest.

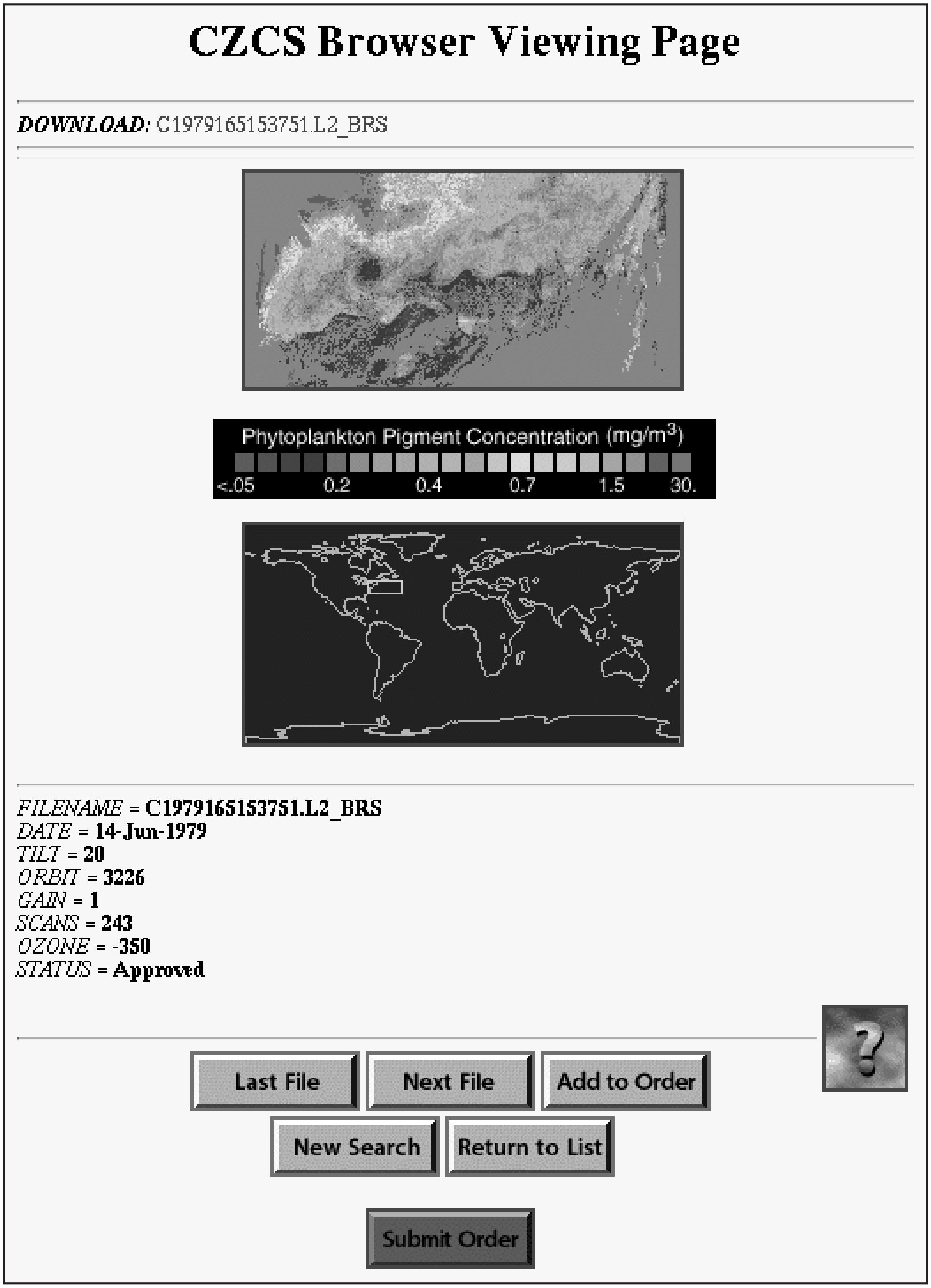

Figure 2. A gif image of the HDF browse file, its exact area of coverage on a global map, and some of the metadata associated with that file are displayed on the Viewing page.

Delivering NASA's Latest Discoveries to Teachers

Karen Alcorn, Frank Kronberg, and Isabel Hawkins, Center for Extreme UltraViolet Astrophysics, University of California at Berkeley

The Center for Extreme UltraViolet (EUV) Astrophysics (CEA) at the University of California at Berkeley is developing a World Wide Web (WWW) information server tailored to the needs of time-starved teachers. This server will allow teachers to quickly develop lesson plans incorporating NASA's latest discoveries.

CEA processes and archives enormous amounts of data sent from NASA's Extreme Ultraviolet Explorer (EUVE) satellite. EUVE, launched on June 7, 1992, is an Earth-orbiting satellite with telescopes that view light in the EUV band of the electromagnetic spectrum. EUVE has performed without a hitch for over three years.

CEA's information server contains EUVE data organized into single multimedia information packets that can be obtained through online WWW requests. Request delivery will be customized according to criteria determined by the user, such as: topic requested, level of detail, academic level, and bandwidth (speed of transmission between CEA and user).

How it will work

Imagine you are a busy teacher. After you access CEA's information server through the WWW, you will select a topic. The topics fall broadly under NASA's Chief Administrator, Daniel S. Goldin's, primary research areas for the space sciences: sun-Earth system, exploration of our solar system, origin and discovery of other planetary systems, and structure and evolution of the universe. You may choose a topic from these three categories: Teacher-developed Lesson Plans, CEA-developed Tutorials, or Other CEA Topics. The topics of the Teacher-developed Lesson Plans are:

- Doing Astrophysics Research with an Artificial Earth Orbiting Satellite
- The Electromagnetic Spectrum
- Images of the Universe in Different Wavelengths
- Satellite Communications
- Solar System Objects

The topics of the CEA-developed Tutorials currently are:

- Be an Engineer—Learn How to Operate a Satellite
- Be a Scientist—Learn How to Become a Space Researcher

Future tutorials will include:

- NASA and the Explorer Program
- The EUVE Mission
- UV and EUV Radiation and the Electromagnetic Spectrum
- The EUVE Satellite
- The EUVE Science Payload and Instrumentation
- The Center for EUV Astrophysics
- The EUVE Science Operations Center
- Training for Payload Controllers
- Science Highlights and Discoveries of the EUVE Satellite

The Other CEA topics are:

- Instrument Hardware
- Instrument Software
- Science
- Communication
- Administrative

Once you have chosen your topic, determine the amount of detail desired, the complexity of the information that suits your target audience, and the format for transmission according to the bandwidth available. For detail you may choose from the options: two to three lines

(Definition), two to three paragraphs (Introduction/Synopsis), or one page or more (Longer article). The level of complexity of the information is geared to your students' academic abilities: junior high, senior high, college, or graduate level. Finally, select a transmission format. For low bandwidth users, a text-only version of the information is available. Medium bandwidth users can access graphics. For high bandwidth users, animation is available.

After selecting the parameters, you will send in your request. Your request will return, for example, an in-depth description, graphic, and animation of the EUVE satellite hardware, targeted for the abilities of your high school students. If you decide to change your request, the flexible interface will allow you to do so.

Diversity of users

In addition to kindergarten through grade 12 educators and students, CEA's information server will be accessed by other users: guest scientists and other professionals in the astrophysics community and interested amateur astronomers, engineers, and technicians from other science projects and from space technology companies. Internet surfers from the general public and users from within CEA and the EUVE Project will also access the information. The design of the server will enable these users to choose parameters to suit their needs. CEA's information server may become an effective model of how data and information from any NASA satellite mission are delivered to a variety of users via the WWW.

A prototype of the CEA information server is scheduled for release April 1, 1996. Watch the CEA home page for release of the CEA information server at:

http://www.cea.berkeley.edu

Online lesson plans are currently available at:

http://www.cea.berkeley.edu/Education

For further information contact Frank Kronberg at:

510-643-7217
kronberg@cea.berkeley.edu

Nelli Levandovsky, a San Francisco physics teacher, created the tutorial outlines. This work is supported by NASA contract NAS5-29298 and grant NAG5-2875. The Center for EUV Astrophysics is a division of UC Berkeley's Space Sciences Laboratory.

Corrections

Please note a correction to the article, "Global Data Available" (Issue 37, Volume III, page 22). Piers Sellers was incorrectly listed as a Hughes STX employee. Sellers is a Goddard Space Flight Center employee. The author, Blanche Meeson also wishes to acknowledge the GEWEX project for participation and support of this effort. To order CDs and download data from the Goddard Distributed Active Archive Center access http://daac.gsfc.nasa.gov/

Also, please note the correction to "Accomplishments," Ames Research Center, page 45. The accomplishments listed are for the NASA Science Internet (NSI). Our apologies.

Perspectives on an Ocean Planet —The TOPEX/Poseidon Informational CD-ROM

Dave Hecox and Mike Martin, Data Distribution Laboratory, Jet Propulsion Laboratory

The Data Distribution Laboratory (DDL) has supported the production of *Perspectives on an Ocean Planet,* the TOPEX/Poseidon Informational (TPI) CD-ROM that describes the TOPEX/Poseidon mission from conception through operations. This CD-ROM is designed to supplement the posters, lithographs, brochures, and videotapes typically distributed for public relations purposes. It attempts to capture most of these mission products in a single, inexpensive disc that can be replicated for little more than a dollar a copy.

What is an informational CD-ROM?

The TPI CD-ROM can be likened to a coffee-table book with beautiful color images and interesting stories to tell. It provides seven chapters that include 34 Quicktime movies (totaling about one hour of video) and 44 images and captions. A graphical table of contents is available for navigation, as well as a slide show mode that will guide the viewer through the entire presentation. The objective is to provide a comprehensive story about the mission. A secondary goal, from the DDL perspective, is to demonstrate the effective use of multimedia segments to describe complex instruments and data sets.

A key technical challenge of any multimedia presentation is to display content (images, movies, animations) that will work even on a modest computer platform. This may not sound like a big challenge, but in reality it requires incredible effort and is rarely done successfully on multimedia titles produced to date. The mission products, which comprise the raw input to the multimedia application, are usually produced in formats that are unsuitable for direct conversion to the limited resolution (640 x 480 pixels) of most computer screens. This demands that most products be edited and reformatted for use in the multimedia product. Video segments constitute an even greater burden with image size, playback speed and color management all conspiring against the developer.

Project design

The TPI CD-ROM is the first DDL product to use a master-content database with tools to extract and produce various versions of the presentation. The previous experience developing *Welcome to the Planets* CD-ROM and the *Mars Upper Atmosphere Dynamics, Energetics, and Evolution Educational CD-ROM* demonstrated that a more formal development approach was needed. In these products much of the content was captured and stored in the multimedia presentation program, Macromind Director. For example, in the first version of *Welcome to the Planets* the text captions were embedded in the Director application. In order to create an hypertext markup language (HTML) version of the presentation, a C program had to be written to search through the application and extract the captions. This architecture also made it very hard to maintain consistency between elements of the production (text captions, audio captions, HTML captions).

Figure 2 shows the development architecture used to produce three versions (Mac, PC and HTML) of the application. The front end of the development architecture is a set of screen

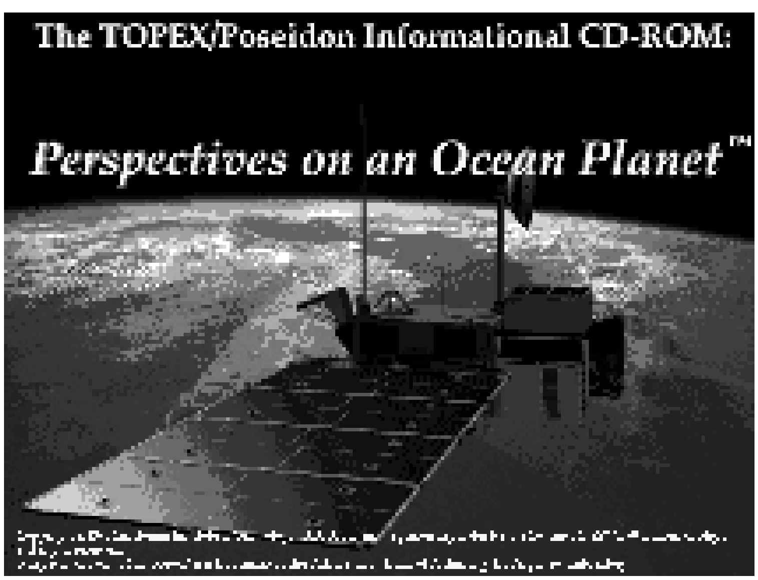

Figure 1. Cover image of the TOPEX/Poseidon Information CD-ROM

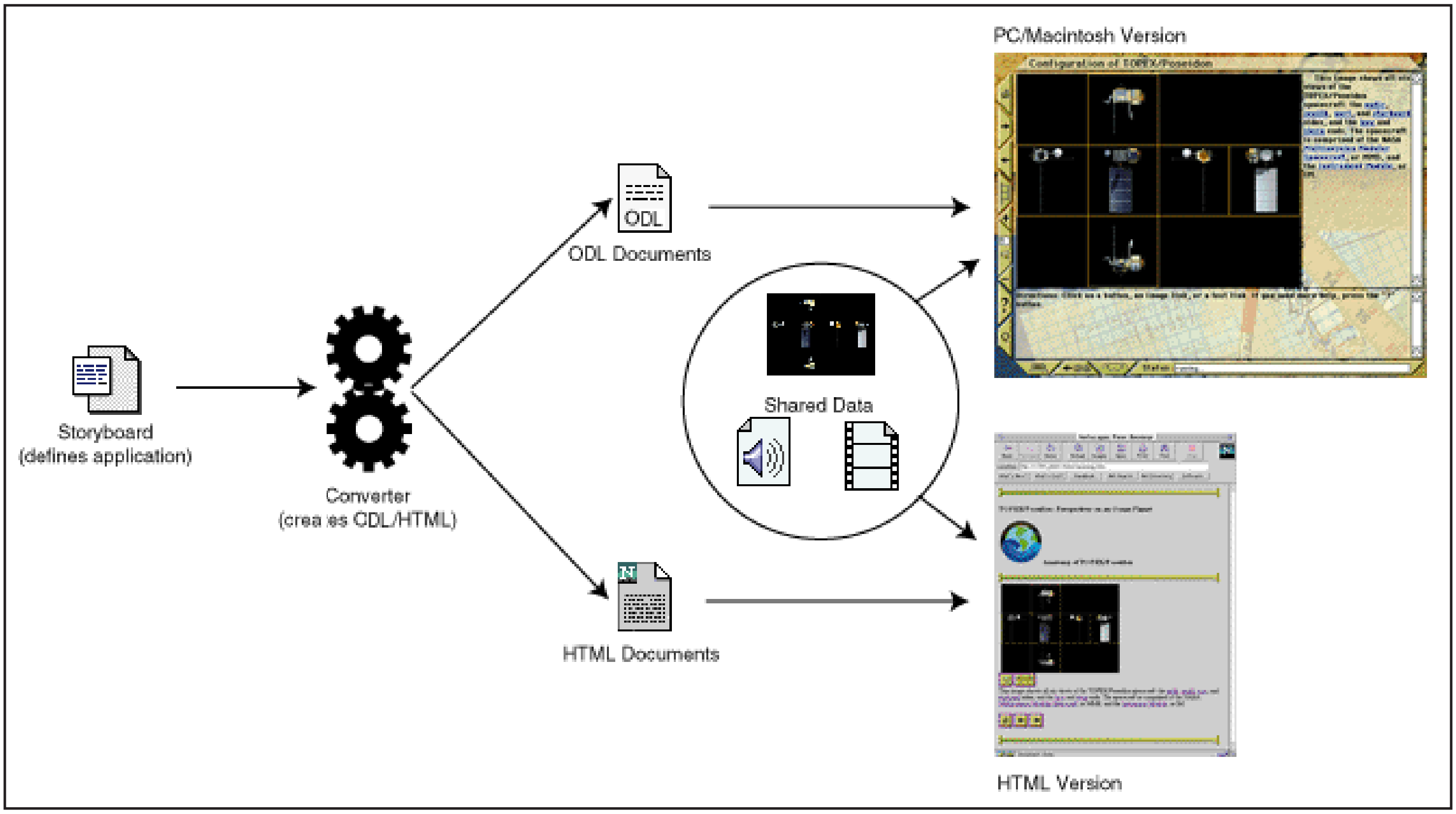

Figure 2. Development architecture

descriptions or storyboards created and maintained in a text file (commercial scripting tools were evaluated but rejected). The storyboards contain all the information about each screen in the presentation. This includes the caption, the images, and video to use for the screen and the hypertext and glossary links. The storyboard is essentially the recipe used to produce the application, as in the example "Take video segment 13 and add caption 27 with links to screen 23, 27, and 33 then add audio segment 9, starting 22 seconds into the video." In order to change the presentation, only the storyboard and the associated content files need to be changed. Because all three versions of the application use the same storyboard, the change only has to be made once.

A special program reads the storyboard file and produces both an Object Definition Language (ODL) version (the data description language developed by the Planetary Data System) of the presentation and an HTML version. The ODL version is read dynamically by a Macromind Director script that plays the program, displays or plays the proper multimedia files, and provides the functionality to navigate. The HTML version can be read by any Web browser, on any platform, and will be placed on the TOPEX/Poseidon home page for internet access.

User interface

The TPI CD-ROM includes several new interface elements to allow you to navigate the material and to increase the interactivity of the presentation. The visual table of contents (Figure 3) presents a representative image for each topic that is instantly displayed as you roll the cursor over the topic heading. The user interface includes navigation buttons along the left side of the screen: home to table of contents, step forward, step back, present a slide show, audio volume controls, help and quit. The buttons along the bottom are: print, return from hypertext jump, zoom, and a status message area. The buttons were designed to be interesting to the target audience (middle school).

Embedded in the caption text are hyperlinks to other topics and links to glossary entries (in italics - note the definition of port in the lower window of Figure 4) that define or describe terms used in the caption. There are also roll-over links that activate pointers on the image to identify the exact location of some region of interest (see the box around the high-gain antenna in the image below). The images also have back links to the caption text, so the mouse rolling-over a marked portion of an image causes the corresponding text in the caption to be highlighted.

Staffing

The core development team consisted of three people: a full-time producer, a full-time content developer, and a half-time graphic artist for nine months. The producer was responsible for the software shell, the look and feel of the interface, and the architecture of the disk. The content developer was responsible for the development of the material on the disk, and for running the peer reviews. The graphic artist created interface elements under the direction of the producer, and created content for the CD under the direction of the content developer.

The staff of the DDL was called on to assist in other areas as needed including CD-ROM and HTML expertise, audio recording, and the development of cross-platform tools for printing. Some of the spacecraft animations were contracted out to a commercial artist. Development costs were kept to a minimum by calling on these specialists only for short, concentrated periods of time. Total labor costs for the project were on the order of $200K.

Data preparation

Most of the content for the presentation was derived from hard-copy products. The original digital versions of artwork were generally not available or were not in a format that could be used. The images were scanned at 300 dpi and converted to 8-bit using an optimized color pallet of 206 colors (50 colors were reserved for screen management). Debabalizer was used on a Macintosh to perform the color palette manipulation.

The videos were captured in Quicktime format on a Radius Video Vision Studio system at 320 by 240 pixels at a rate of 15 frames per second. The videos were then edited into their final form with Adobe Premiere and compressed using the Cinepak codec (compression/decompression algorithm). The size of the compressed video clips is about 20 times smaller than uncompressed full-color video. The compression took from one to two hours per minute of video on a Macintosh Quadra 840 AV (33 mHz processor). The target frame rate was set to 200 kilobytes per second to allow playback on a double speed CD-ROM reader. Table 1 summarizes movie parameters for several movies. The data size averages about 10 megabytes per minute and the animation sequences compress twice as well as the video sequences. In order to provide optimal color playback, the movies were analyzed using Debabalizer and a single optimized color palette produced for each movie. This optimized palette is used by Macromind Director when the movie is played.

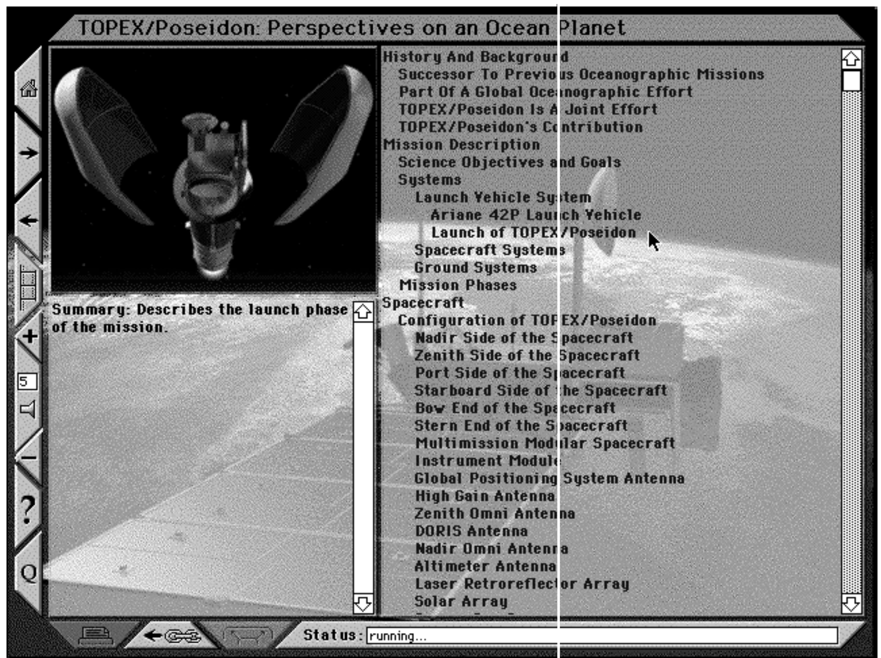

Figure 3. TPI CD-ROM visual table of contents

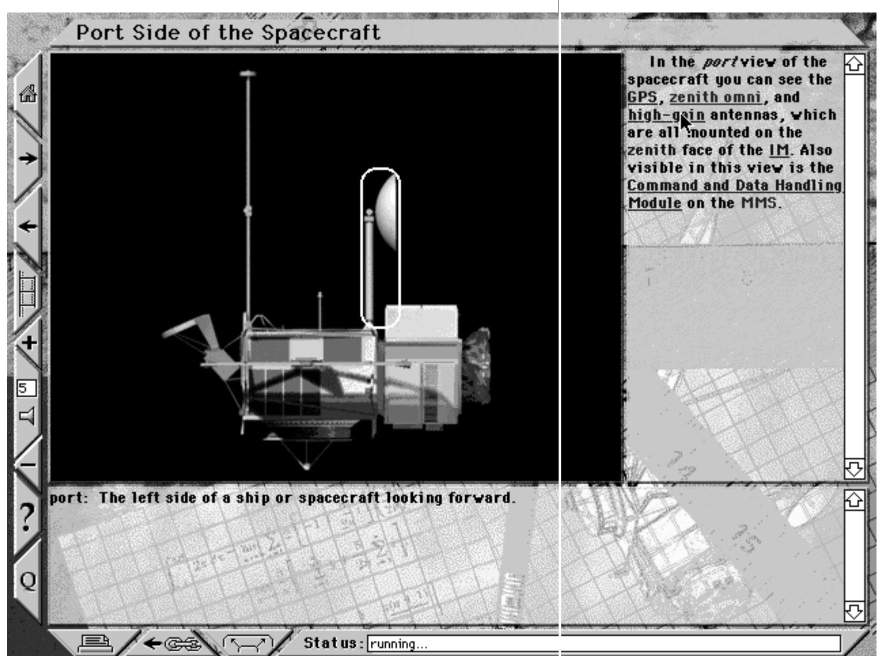

Figure 4. Sample topics screen

Future directions

The DDL is currently producing educational CD-ROMs for NSCAT, Cassini, and TOPEX/Poseidon that include curriculum components desired by educators. These products will take advantage of the methodologies developed in

Table 1. Quicktime Movie Parameters

Table 1

Movie Name	Data Size	No. of Frames	Elapsed Time	Playback Rate	Content
Climate.mov	14.5 megs	1278	1:25 min	173 KB/sec	anim+video
Launch.mov	17.0 megs	1533	1:42 min	171 KB/sec	anim+video
Surface.mov	5.3 megs	918	1:01 min	90 KB/sec	anim
Systems.mov	10.9 megs	809	0:54 min	206 KB/sec	video

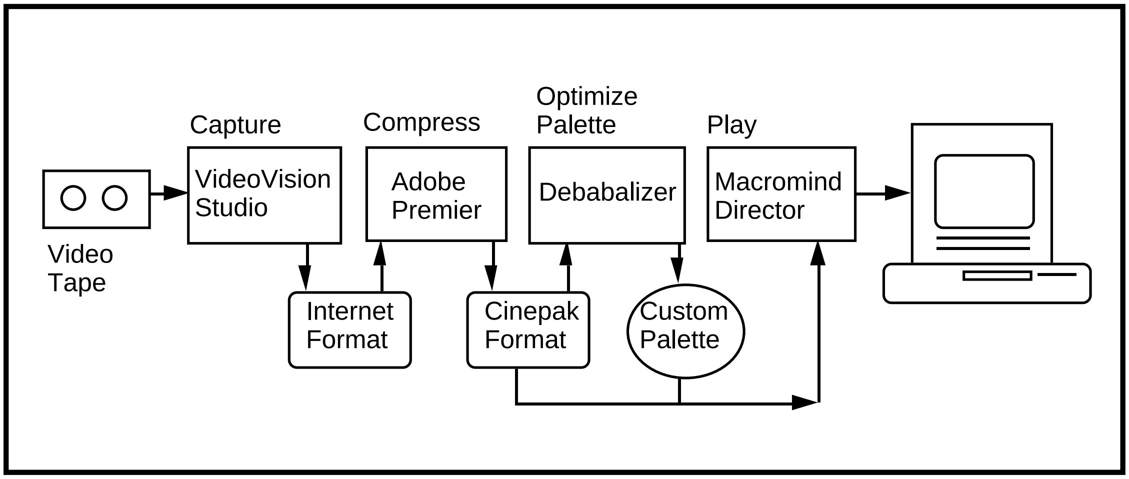

Figure 5. Quicktime movie processing

producing the TPI CD-ROM. By designing this production system, two additional benefits were realized for future productions; the robust foundation that was created is now in place and future development costs will be substantially reduced. The engines used to produce the various versions of the presentations will be ported to other platforms, probably using the JAVA language.

There have been a number of articles written recently criticizing the glut of multimedia educational products and touting the advantages of printed books. While many products do not take advantage of the media, there is incredible potential for presenting complicated instruments and data products with multimedia animations. The use of sound is another important capability. One of the most powerful segments of the TPI CD-ROM presents the earth-shaking roar of the Ariane rocket launch.

The informational CD concept represents an effective new product for presenting a mission's information to the scientific and educational community. The DDL staff is eager to work with other projects to develop similar products so that NASA can provide a comprehensive library of mission informational presentations.

Copies of the TPI CD-ROM can be obtained from the PO DAAC at :

podaac@podaac.jpl.nasa.gov
http://podaac.www.jpl.nasa.gov
818-354-9890

The TOPEX/Poseidon project staff and project scientists provided content, careful review, and guidance throughout this task. Dave Hecox produced the TPI CD-ROM. Vicky Barlow was the content developer. Randy Oliver was the graphic artist. The DDL staff participated in the development or testing (Margaret Cribbs, Yolanda Fletcher, Adrian Godoy, Sue Hess, Kristy Kawasaki, Mike Martin, Sugi Sorensen, Mark Takacs). Don Davis produced the spacecraft models and animations.

Converging Computing Methodologies in Astronomy

Maria Concetta Maccarone, Istituto di Fisica Cosmica ed Applicazioni all Informatica, Palermo, Italy, and Fionn Murtagh, Space Telescope—European Coordinating Facility, Garching, Germany

A three year European project in computational astronomy, Converging Computing Methodologies in Astronomy (CCMA), was started in 1995 under the aegis of the European Science Foundations. The aims of the project and its workshop discussions are described herein.

The increasing integration in an astronomical setting of various methodologies in pattern recognition, information retrieval, and data analysis is a characteristic of modern computational astronomy. Large astronomical databases and archives from space-borne missions, ground-based observatories, and large wide-field surveys, provide the technological infrastructure. Against this backdrop, boundaries between theoretical domains have been lowered. A number of leading cases, and lessons to be drawn, are described briefly as follows:

- Automated galaxy counts from digitized images (e.g., through use of the COSMOS machine in Edinburgh, or with the MAMA machine in Paris) lead to a fundamentally new vision of the Universe. The problem here goes considerably beyond image analysis; it raises various other problems that are solvable with pattern recognition and statistical methods. The number of objects treated, in this instance and in applications to be described in the following, may be many tens of millions.
- The use of large image databases and archives necessitates new image retrieval and textual retrieval methods. The latter includes both image-associated descriptive text, and also retrieval from bibliographic databases. Modern astronomical retrieval systems allow seamless access to information in its varied forms (graphical, image, textual, bibliographic, etc.), alongside semantic support (e.g., name resolvers).
- Multiresolution image analysis, mathematical morphology, and fuzzy object characterization are increasingly integrated. Thus, wavelet transform analysis is used for image restoration and filtering, with semantics built in through morphological operations on the transform. Fuzzy object characterization is a valuable interpretational facet.
- Cross-identification of large catalogs (Infrared Astronomical Satellite, Roentgen-Satellite, etc.) are necessary, both for scientific analysis and as an indispensable basis for missions (e.g., the Hipparcos Input Catalog). Cross-identification of data is one aspect; a further turn of the same spiral leads to the issue of the cross-correlation of information.

The astronomical application domain offers a unique test-bed for establishing strengths and limitations of these methodologies (and it offers in addition an exportable model for other domains also). Astronomy is an online, nearly all-digital science, with high visibility, and a specifiable research community. These characteristics provide a fertile basis for dissemination of research results. A major goal of the CCMA network is a position paper on this area—*Computational Astronomy in Europe*.

Workshop activities

A workshop on vision modeling and information coding (the nature of the information that can be obtained and its computing, statistics, and pattern recognition expression) was held at Observatoire de la Côte d'Azur this past October. Topics included wavelets and multiresolution; vision models and content-based image retrieval; compression and mathematical morphology, to name a few. Such issues cannot be separated from analysis methodologies, nor from the astronomical semantic context. A preliminary version of the proceedings is available via the CCMA home page (http://www.eso.org/conv-comp.html).

A second workshop on information management (textual, bibliographic, graphical, and image data in their dynamic aspect: production, selection, storage, processing, maintenance, retrieval, and integration) will be held in Strasbourg, France, in June 1996. Topics will include perspectives from some major astronomical publishers and those involved in public outreach, as well as overview of topics such as natural language processing and vision research, and neural networks in information retrieval.

A third workshop (date and place to be announced) will be held on data and information fusion, integration, and classification (catalog cross-referencing and classification, new spatial relational database concepts, and coordination issues raised by interactive sky atlases). Overview theory and applications of data fusion in remote sensing will be presented.

Lastly, a large conference on the project's overall theme will be held, shortly before the project ends, at Sonneberg Observatory, Germany, on September 7-10, 1997, in conjunction with Astronomy from Large Databases III. This conference will be held with the aim of bringing the results obtained to a wide audience. A selected set of papers will be published in book form.

For further information access the CCMA Web page or contact Fionn Murtagh at:

fmurtagh@eso.org

Acknowledgments

The many individuals who collaborated on the CCMA home page and who participated on the coordination committee include:

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Science Videos on the Move

Judy Laue, Contributing Editor, Hughes STX, Space Data and Computing Division, and Jarrett Cohen, Science Writer, Hughes STX, High Performance Computing Branch, Goddard Space Flight Center

Observations and supercomputer models are powerful tools used to study Earth and space. These tools often result in billions or trillions of bytes of data, in a form not easy to understand. Presenting these data as visualizations helps researchers gain greater insight into their work and communicate it to others. Goddard Space Flight Center's (GSFC) Scientific Visualization Studio (SVS) recently produced six videos that illustrate science performed at GSFC and other institutions. Information about each of these videos is presented below.

Images of Earth and Space: The Role of Visualization in NASA Science

Co-producers: Pamela O'Neil, HSTX/SVS and Jarrett Cohen, HSTX

Approximate running time: 16 minutes

This narrated production displays 16 visualizations sponsored by GSFC's NASA Center for Computational Sciences (NCCS) and the NASA High Performance Computing and Communications (HPCC) Program's Earth and Space Sciences (ESS) Project. Among other phenomena, viewers can swim through the abundant world under the ocean, hover above the Antarctic "ozone hole," tour the Moon's rocky surface, probe the boiling interior of the sun, and witness the transformation of a spiral galaxy into an elliptical galaxy. Electronic music enhances the visuals.

Explaining each project at the lay level, the tape is designed to be useful to the news media, students, government officials, and the general public. This film premiered at Supercomputing ’95 in San Diego, CA.

The “Images of Earth and Space” video may be obtained by contacting Jarrett Cohen at:

301-286-2744
jarrett.cohen@gsfc.nasa.gov

Musculoskeletal Modeling Dynamics Simulations
Modeling: Marcus Pandy, Frank Anderson, Brian Garner, University of Texas at Austin

Graphics: Brian Garner

Producer: William Krauss, HSTX/SVS

Approximate running time: 45 seconds

Marcus Pandy, ESS Project Guest Computational Investigator, is studying the forces that act on the human musculoskeletal system while on Earth and in space. The ability to simulate human movement and accurately compute musculoskeletal loading histories is particularly important to the space program, where exposure to gravitational fields can alter morphology, biochemistry, and functional properties of muscle and bone tissue. Moreover, understanding musculoskeletal forces will help identify the role of individual muscles when treating musculoskeletal disorders, enhance surgical procedures for correcting muscle and joint disorders, and improve the design of joint replacements.

The Discovery Channel requested this simulation of a human skeleton in motion for airing in 1996. The video depicts multijoint coordination and muscle function while performing the complex motor task of walking, as modeled by high-speed parallel supercomputers with fast, efficient computational algorithms. A slightly different version of this visualization appears in *Images of Earth and Space*.

Hurricane Florence Mesoscale Simulation Results Using Virtual Reality
George Lai, Edward Rodgers, Mohan Karyampudi, GSFC Laboratory for Atmospheres

Visualizations: Fritz Hasler, Kannappan Palaniappan, GSFC Laboratory for Atmospheres

Virtual Reality: Stephen Maher, SVS

Producers: William Krauss and Stephen Maher

Approximate running time: 5 minutes

This dramatic video shows a virtual reality (VR) representation of a hurricane Florence model run on the NCCS CRAY C98 supercomputer. The Mesoscale Model-5 simulation was visualized using the Visualization of 5D Datasets (VIS-5D) software developed at the University of Wisconsin–Madison Space Science and Engineering Center with support from Marshall Space Flight Center. Researchers employed isosurfaces to signify rain water, cloud water, and a portion of the jet stream. Spiraling ribbons show the air parcel trajectories around the center of the hurricane.

VR has helped the atmospheric scientists learn more about the dynamics of hurricane development and has led to unexpected discoveries; for instance, the rate at which air flowed into the hurricane was much slower than previously estimated. For more information about this work, see *Science Information Systems Newsletter*, July 1995, p. 32.

Solar Modulation of Relativistic Electrons in the Earth’s Radiation
Shrikanth Kanekal, HSTX/GSFC Laboratory for Extraterrestrial Physics

Daniel Baker, Univ. of Colorado, Boulder

Berndt Klecker, Max Planck Instute fur Extraterrestriche Physik, Garching, Germany

Richard Mewaldt, Jay Cummings, California Instute of Technology

Producer: William Krauss

Approximate running time: 7 minutes, 35 seconds

High-energy electrons in Earth’s magnetosphere present a unique opportunity to study basic questions about particle acceleration in space plasmas. In this study, sensors on board the Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX) measured high-energy electrons in Earth’s radiation belts. The Yohkoh SXT (Soft X-ray Telescope) provided concurrent solar images.

The video illustrates the dynamics of the radiation belts. The energetic electrons are accelerated in the radiation belts. The acceleration seems to be due to solar wind streams impinging on the magnetosphere. This video was produced for showing at the fall American Geophysical Union, San Francisco, CA, and for educational purposes.

ISTP/GGS Movie of the Magnetic Cloud Event October 18-20, 1995
Scott Boardsen and Mauricio Peredo, HSTX/ GSFC Space Physics Data Facility

Gordon Rostoker and Hamid al Nashi, University of Alberta

Producer: William Krauss

Approximate running time: 7 minutes, 11 seconds

On October 18, NASA's Wind spacecraft detected a huge magnetic cloud traveling through the solar wind towards Earth at approximately 400 km/s. The cloud engulfed Earth and took about 30 hours to pass by the planet. Magnetic clouds are believed to be magnetic flux ropes expanding away from the Sun with ends tied to the Sun's surface. Such clouds can trigger magnetic storms and substorms, in turn sparking brilliant Auroral displays (the "Northern Lights"), power line surges, and communication problems.

Using Wind and Canopus groundstation data, this movie illustrates the strong interaction between the cloud and geomagnetic activity in the region of space (geospace) strongly influenced by Earth's magnetic field. Multiple panels simultaneously show 1) the passage of time; 2) bar charts of solar wind pressure and the strength of the northward/southward component of the cloud's magnetic field; 3) an artist's rendition of the cloud proceeding from the Sun; 4) the Auroral oval, the area where electrons are striking and depositing energy into the upper atmosphere; and 5) the solar wind interacting with the Earth's magnetopause and bow shock (the magnetopause, or the boundary between the magnetic fields of the Earth and the Sun, is an obstacle to the solar wind, and the bow shock develops to deflect the solar wind around it).

Assimilation of N_2O with a Kalman Filter in the Middle Atmosphere
Lihsiung Chang, Stephen Cohn, Peter Lyster, and Richard Menard, GSFC Data Assimilation Office

Producer: William Krauss

Approximate running time: 2 minutes, 31 seconds

Nitrous oxide (N_2O) is a greenhouse gas produced through ocean biological processes and brought into the stratosphere by atmospheric motion. In the stratosphere N_2O can deplete ozone and increase atmospheric temperature by absorbing infrared radiation. Levels of N_2O are being carefully monitored because the long-term behavior and effects of too much N_2O in the stratosphere are not yet known.

Observations taken by the Cryogenic Limb Array Etalon Spectrometer on the Upper Atmosphere Research Satellite are combined with a model-forecast N_2O field using winds from the Goddard Earth Observing System Data Assimilation System to produce the best estimate of the N_2O mixing ratio at each time step during a four-day period beginning Sept. 2, 1992. To illustrate how robust the assimilation system is, a null initial condition of N_2O mixing ratio is used. The first animation in the video displays the N_2O mixing ratio in parts-per-billion volume as a function of time and space. The second animation shows the error correlation between a material particle and all other grid points. This work was performed as part of an ESS Project Grand Challenge investigation.

For further information about these videos contact the SVS at:

301-286-4101
or Dr. James Strong at:
301-286-9535
strong@leaf.gsfc.nasa.gov.

For further information about the sponsoring organizations see the following World Wide Web pages:

NCCS: http://sdcd.gsfc.nasa.gov/NCCS/

SVS: http://sdcd.gsfc.nasa.gov/SAVB/SVS/

NASA HPCC Program:

http://cesdis.gsfc.nasa.gov/hpccm/hpcc.nasa.html

ESS Project: http://sdcd.gsfc.nasa.gov/ESS/

GSFC Laboratory for Extraterrestrial Physics:

http://lep694.gsfc.nasa.gov/code690.html

GSFC Data Assimilation Office:

http://hera.gsfc.nasa.gov/dao.home_page.html

Newly Formed NASA Internet Combines NASA Science Internet and AEROnet

Christine Falsetti, NASA Internet, Ames Research Center

Wide area networks at Ames Research Center have been consolidated into the newly formed NASA Internet (NI), an operational testbed that will deliver high-performance systems to NASA's science and engineering communities and integrate internetworking technologies into NASA aeronautics and space missions. The updated name combines the NASA Science Internet and Numerical Aerodynamic Simulation AEROnet communities under one office, concentrating on internetworking technologies. Continuing the long-standing precedent established by NASA Science Internet and AEROnet as early adopters and integrators of the latest technology, NI will continue to work with industry and academia to research and develop these technologies, promote interoperability and integration, and deliver end-to-end systems to our customer base.

For further information contact the author at:

christine_falsetti@gmgate.arc.nasa.gov

NASA Internet Provides Conference Support

Pat Kaspar, Contributing Editor, Ames Research Center

The NASA Internet (NI), formerly the NASA Science Internet (NSI), routinely provides Internet connectivity to a growing number of scientific conferences each year. Provision of this service at conferences allows scientists greater flexibility in demonstrating their research to colleagues. It also permits them to stay cognizant of developing events in near-real time when away from their home base.

An example of NI's service is the support provided to the Division for Planetary Sciences (DPS) Annual Meeting held Oct. 8-13 in Kona, Hawaii. Internet e-mail connectivity at the conference consisted of 12 systems provided by NI and the University of Hawaii. This allowed the estimated 650 attendees to gain faster access to their e-mail than is customarily available at conferences. NI also demonstrated a World Wide Web information search browser. Additionally, a work room where several terminals were set up, removed from the demonstration area, provided a quiet area for work.

Internet connectivity at the DPS conference provided the first news that the Galileo Jupiter-bound spacecraft tape recorder was experiencing problems. It also permitted dissemination of new Hubble Space Telescope images showing discovery of ozone on Jupiter's satellite, Ganymede, a possible new active volcano on Jupiter's moon Io, and an aurora on Saturn.

"Scientists have expressed their thanks to NI for providing conference support, both personally and in e-mail messages," said JoAnn Nelson, NSI requirements manager for Solar System Exploration."

NI has been providing Internet connectivity to scientific conferences by innovative cost-sharing arrangements. Under these terms, NI provides the travel, equipment, engineering, and networking coordination and support personnel, while the scientific organization provides for conference circuit costs, booth fees, etc. Look for NI support at the following conferences:

- American Geophysical Union (AGU), May 20-24, 1996, Baltimore, MD
- American Astronomical Society (AAS), June 9-13, 1996, Madison, WI
- The Oceanography Society (TOS), July 8-11, 1996, Amsterdam, The Netherlands

For further information on NI conference support contact Kris Orabona at:

415-604-0857
kris@nsipo.nasa.gov

NASA Internet Helps US Agency for International Development Expand Internet Sites

Pat Kaspar, Contributing Editor, Ames Research Center

As the global Internet infrastructure continues to expand, it is rapidly propelling developing countries into the 21st century. As part of a Memorandum of Agreement (MOA), NASA is working to help the US Agency for International Development (USAID) achieve a virtually private, fully integrated, low-cost, TCP/IP-based internetwork for its many missions around the world. These missions include sites in Central and South America, Africa, and the Far East. With the completion of this internetwork, each USAID mission will join the private internet that gateways to the global Internet through USAID's headquarters in Rosslyn, VA.

USAID and NASA telecommunications interests are complementary. USAID implements programs that further American interests, such as improving health and population conditions, promoting economic growth, protecting the environment, and supporting democracy. The NASA Internet (NI), formerly the NASA Science Internet, works closely with various national and regional networks as partner in the global Internet infrastructure. It has extended Internet connectivity to more than 20 countries and provides requirements management, network engineering, continuous network monitoring, and user assistance. Both agencies consider reliable telecommunications essential to accomplishing their missions.

Under the MOA with NASA, USAID draws upon NI engineering consultation resources to design a reliable and robust, yet cost-effective network. The communications system designed by NI establishes the infrastructure backbone for USAID internetworking requirements. This system includes state-of-the-art Very Small Aperture Terminal (VSAT) satellite systems using Time Division Multiplex Access (TDMA), and end-to-end TCP/IP technologies, and it will integrate commercially available off-the-shelf products and services.

Global satellite coverage for USAID sites depends on a family of satellites whose combined "footprints" cover the world. Initially, two satellite downlink stations will act as network hubs into the Internet; one in Andover, Maine, and one on the outskirts of London. These stations in turn route through USAID Headquarters for access to the global Internet, including resources such as NI, other federal networks, and commercial service providers.

In addition to design engineering, NI coordinated with third-party organizations such as Lyman Brothers (a satellite systems integrator), NISE-West, MCI, and Comsat to meet all aspects of the design requirements. NI also provided consultation on IP addressing, routing, and Internet security, and it will provide ongoing consultation on bringing up the next wave of sites in the Indian Ocean area.

The VSAT/TDMA solution used for remote USAID sites is being explored for use in other areas as well. For example, some NI requirements that have not previously had a cost-effective solution due to their remote location may now be satisfied with this technology.

For further information on NI's support of USAID, contact Roxanne Streeter-Evans at:

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streeter@nsipo.nasa.gov

Mission to Planet Earth Technology Aids in Fire Fighting

A NASA research aircraft played a critical role in fighting a major fire that threatened life and property in the Scottsdale and Fountain Hills areas of Arizona last summer. The plane, a C-130B based at Ames Research Center (ARC) was in the area collecting geological data for Mission to Planet Earth. The plane was equipped with a host of data gathering devices and photographic equipment, including thermal scanners able to penetrate thick smoke and clouds.

Observers on the plane saw the fire while on approach to Phoenix on July 8. Mission manager Chris Jennison obtained clearance from ARC to document the fire and assist local emergency management personnel. Three high altitude flights with the ability to cover a wide area were immediately flown and data was recorded on videotape. These tapes were delivered to Scottsdale officials upon arrival at Sky Harbor airport for use by the incident commander, Jeff Whitney. Subsequently, additional help with flights before dawn on July 9 were requested. Because the on-board instruments had the capability to penetrate both smoke and darkness, and peer into hidden canyons, local mapping experts and other observers aboard the C-130B were able to record changes and significant events within the fire perimeter and transfer that information to command maps for rapid distribution to fire fighting personnel. The aircraft provided visual evidence of the existence and location of dangerous remaining hotspots on its black and white video monitors.

"NASA played a direct role in controlling the 23,000 acre fire that threatened the communities of Scottsdale and Fountain Hills this weekend," Wilson Orr of the Scottsdale City Manager's Office said in a letter to NASA Administrator Dan Goldin dated July 12. "The C-130 based at Ames Research Center was made available with its unique instrumentation capabilities, which include infrared sensors capable of fire detection. This use of 'Mission to Planet Earth' resources to help us manage local emergencies for the preservation of life and property is a significant return on taxpayer investment. We appreciate the practical value of this program."

"With pre-dawn flights, we were able to accurately identify the fire perimeter showing overnight changes in fire intensity and spread," Orr said. "This was invaluable information in deploying limited resources to protect threatened life and property. The C-130 crew also identified a two-mile change in the fire front which let the fire team deploy this morning with greater accuracy and safety."

Information excerpted from NASA press release 95-116.

NASA's wealth of technology is being re-used in the fields of medicine, industry, and education and by the military to develop products and processes that benefit many sectors of our society. Spinoff applications from NASA's research and development programs are our dividends on the national investment in aerospace.

Publications

Editor's Note—*NASA/Office of Space Science is proud of the contributions many of its science and applications research, scientist, engineers, and writers make to professional organizations and publications. If you have recently been published and would like to be noted in this publication, please send information regarding your written work to: sandi_beck@iplmail.jpl.nasa.gov*

Petaflops Computing: A Fast Ride in a Cold Machine
Jarrett Cohen, *Wired*,
February 1996

Ancillary Data Services of NASA's Navigation and Ancillary Information Facility
Charles H. Acton, *Planetary and Space Sciences*, Vol. 44, No 1, pp. 65-70

Technology 2005—A Showcase of New and Emerging Technology

The sixth national technology transfer conference and exhibition took place in Chicago, Illinois, this past October. Technology 2005 hosted approximately 130 federal labs, universities, and high-tech commercial firms (US and international) demonstrating a wide array of inventions and products available for license, joint development, or sale. The advanced technologies being presented encompassed the fields of manufacturing, computing, communications, environmental quality, materials science, medical technology, microelectronics, display/imaging technology, power and energy, robotics, sensors/instrumentation, and global positioning systems.

In addition to the exhibits, the three day program consisted of various workshops (licensing, patents, entering into cooperative agreements, applying for small business grants, contracting or partnering with government agencies, and marketing), Internet training, and symposia on the fields of technology mentioned above. The plenary session presented "Transportation Tomorrow", Communication 2005", and "Pathsetting Environmental Programs". These sessions focused on technology breakthroughs and key alliances that may shape the future in the fields on transportation, digital communications, and environmental technology.

NASA Administrator, Daniel S. Goldin, fields a question from an unidentified reporter.

The conference was formally opened with a welcome speech by Chris Coburn, the director of the Great Lakes Industrial Technology Center. NASA Administrator, Daniel S. Goldin, was the keynote speaker. Mr. Goldin highlighted NASA's research and development programs which benefit industry and spoke of the value that NASA-developed technology brings to the nation at large. "Transfer of technical knowledge through various sectors of government, education, and industry is growing more critical," he said. He also later emphasized to reporters, regarding dual use, "We don't want to subsidize industry. Our priority is how [dual use] benefits NASA."

Goldin also introduced NASA's new Internet technology tracking service, the Commercial Technology Network, which contains 15,000 technology entries that can be sorted by topic, company, state, and other identifiers. This tracking service is available at:

http://nctn.hq.nasa.gov

The NASA Pavilion

The NASA Pavilion presented over 50 different technology opportunities with industry, transportation, health care, energy, environmental quality, information and communication, materials and manufacturing technologies. The focal point of the pavilion was the NASA Feature Area, which showcased a number of commercialization success stories, including robotic technologies now used in the medical industry, and telemedicine demonstrations providing patient care over long distances. For example, the Hubble Space Telescope displayed a breast biopsy system using charge coupled devices that may replace surgical biopsy, and the University of Texas Health Science Center, in partnership with NASA, Sprint, and VTEL, showcased advances in telemedicine for Texas physicians in caring for tuberculosis patients and children with cancer. Other exhibits in the Feature Area spotlighted the Mission to Planet Earth display, and robotics, telepresence, and remote sensing technology demonstrations.

There was a technical assistance booth to respond to requests for assistance with technical problems, a booth that presented the newest search engine, TechTracS, on the World Wide Web for finding NASA technologies (http://www.gsfc.nasa.gov/NASA_homepage.html), and additional Hubble Space Telescope demonstrations. The Bay Area Multimedia Technology Alliance, a private/public research alliance formed in cooperation with Ames Research Center (ARC), demonstrated networked multimedia technologies and applications.

Additionally, a NASA-Spinoff technology, Augmented Virtual Vision, was demonstrated. The Augmented Virtual Vision tool, which evolved from virtual reality technology, allows the wearer to view video information projected in front of his vision, while simultaneously staying in touch with his surroundings and receiving supporting data to aid in his task. This lightweight, hands-free device has many applications. An airline mechanic, for instance, can carry a complete set of aircraft drawings (without using his hands), viewable from any head position, This particular application is being developed under a government Advanced Research Projects Administration contract. Other examples include the use of this device as a medical visual aid to view endoscopic internal positioning while keeping eyes fixed at the point of entry; use in in-flight space shuttle repair, where step-by-step instructions are necessary; use by military personnel during missions to receive audio and visual data about conditions; and dozens of other industrial, governmental, and commercial applications.

Exhibits in the medical/sensor/instrumentation technologies arena included:

- Johnson Space Center (JSC)—the NASA-DeBakey ventricular assist device and a microwave heart catheter
- Goddard Space Flight Center (GSFC)—a bio-capillary pump loop that was originally developed for spacecraft temperature control, as well as a capaciflector, a capacitive proximity sensor that virtually eliminates thermal drift problems
- Langley Research Center (LaRC)—an electronic, all-digital x-ray breast imaging system
- Jet Propulsion Laboratory (JPL)—the "camera on a chip, a revolutionary approach to the miniaturization of imaging systems that has applications in electric hybrid vehicles, emergency power systems, and batteries
- Kennedy Space Center (KSC)—a real-time nonvolatile residue monitor that provides real-time measurement of molecular contamination depositions in cleanrooms and other critically sensitive environments, and a portable ultrasonic leak detector, an improved way to detect leaks in fluid systems of launch and ground support equipment

Exhibits in the information/communications technologies arena included:

- JSC—an intelligent computer-aided training system that supports rapid development and low-cost maintenance of diverse training applications with significant cost savings; an image pattern classification method, a portable technique for selling movies and prints on the Internet; and a simulator for assisting real-time software development and integration
- Stennis Space Center—a robotics display system with transparent backlit panels
- JPL—a display of the evolution of global positioning system (GPS) receiver technology and the GPS-inferred Positioning System (GIPSY) software that enables high-precision location determination
- ARC—a telepresence control device that employs virtual reality to provide human operators with a sense of being present in a remote environment; in collaboration with the Federal Aviation Administration, a system designed to regulate traffic flow through congested areas; a 3D design system that reduces development time from conception to prototype production; and the visualization software that aids computational fluid dynamics research
- Lewis Research Center (LeRC)—a communications technology satellite with a "pay as you go" system

The NASA exhibit in the transportation technologies arena was presented by Langley; a low cost electromagnetic nondestructive

"Transfer of technical knowledge through various sectors of government, education, and industry is growing more critical."
—NASA Administrator, Daniel S. Goldin

evaluation tool (NDE) that detects cracks in riveted and welded joints in aluminum and steel.

Exhibits in the energy/environmental technologies arena included:

- Mission To Planet Earth—a display of the New Millennium Program mission
- LaRC—an invention that converts carbon monoxide to carbon dioxide and formaldehyde to carbon dioxide and water at room temperature

“Astro” roams the exhibit hall.

Exhibits in the materials/manufacturing technologies arena included:

- JSC—an all-metal energy dissipater that is designed for maximum energy absorption per unit of stroke
- Marshall Space Flight Center—(in collaboration with Rocketdyne Corporation) various welding tools, techniques for fabricating near-net-shape parts, and environmentally-friendly thermal spray coatings, and a vacuum plasma spray technology used in building near-net-shape parts
- LaRC—a sensor measure mass of a moving filament, yarn, tape, or web; a blind fastener technique to replace or install anchor nuts in blind holes or other inaccessible places; an explosive seam welding technology that enables the joining of a wide variety of metals (dissimilar combinations or with varying thicknesses)
- KSC—a proximity sensor-based collision avoidance system that improves robot safety and dexterity
- LeRC—a silicon carbide-based fabrication technology that produces near-net-shape parts at lower cost; software that predicts the mechanical performance of brittle structures is a function of time and temperature, a thin-film strain gauge; a solid-state sensor system (co-developed with GenCorp Aerojet and Case Western Reserve University) that detects trace hydrogen gas leakage around pipes, connectors, flanges, and pressure tanks; and a display of high-temperature plastic resins

In addition to the exhibits, several of the NASA centers also presented papers or participated roundtable discussions.

This conference was sponsored by NASA, NASA Tech Briefs, *and the Technology Utilization Foundation in cooperation with Federal Laboratory Consortium of Technology Transfer*

The NASA Pavilion—centerpiece of the Technology 2005 Conference.

Using Space Technology to Improve Everyday Life

Jim Doyle, Office of Public Information, Jet Propulsion Laboratory

When disaster hit the federal building in Oklahoma City, the Hi-Shear Technology Corporation of Torrance sent two teams, equipped with the company's emergency rescue cutters, to help in the rescue effort. The pyrotechnic technology these teams brought to the rescue effort proved invaluable in cutting through concrete, steel, and other building materials to reach the injured. This technology was developed by NASA for use in space a generation ago, refined by the Jet Propulsion Laboratory (JPL) and then turned over to the private company. This is just one example of how JPL's space science and technology have given birth to literally thousands of inventions and new techniques over the years, many of which have gone into the marketplace, benefiting the general economy in terms of new jobs and investments.

Transferring technology

Most inventions stem from needs created by proposed new space missions, new ways of supplying power, a need to analyze materials, or new dimensions in communications technology. At JPL new technologies are routed through the California Institute of Technology (Caltech) office of Patents and New Technology, to the NASA Management Office, and then to JPL's commercial Programs Office.

JPL moves its developed technologies into the marketplace in several ways. For example, JPL's Technology Transfer and Commercialization Office oversees programs that handle intellectual property management and the dissemination of technical information. This office also prepares reports on new technology for publication in *NASA Tech Briefs*, an official publication of NASA that is distributed throughout industry and government. JPL also hosts the Technology Affiliates program, wherein individual companies, or groups of companies, may join the program and one-on-one relationships are formed between JPL personnel and company employees. JPL's Small Business Innovation Research program (SBIR) funds small companies to develop technologies for planetary exploration missions. This program encourages participation by socially and disadvantaged persons and minority-owned small businesses.

Success stories

Many technologies that originated in JPL's space sciences are now in the marketplace, with many real success stories over the years. Some examples are:

- Diatek Corporation's use of infrared sensors in a non-invasive thermometer; an instrument now widely used
- Spire Corporation adaptation of JPL technology for manufacturing photovoltaics, optoelectronics, and biomaterials
- Allen Osbourne Associates development and improvement of a portable global positioning system receiver that owes its provenance to JPL's long years of work in space telecommunication
- The Los Angeles County Sheriff's narcotics department's use of JPL's image display software
- Detroit Technologies, Inc.'s work with JPL to develop a clean liquid methanol fuel cell for permanent and emergency power supplies
- Advanced Interventional Systems' use of JPL's laser technology in biomedicine in development of a laser angioplasty instrument to determine artery problems with minimum invasion of the body
- Computer Motion, Inc.'s development of robotic instrumentation for assistance in laparoscopic surgery
- MicroDexterity Systems, Inc.'s, development of a robotic assisted micro surgery device, partnered by JPL

Many inventions and technologies still awaiting licensing have captured the attention of the commercial sector. For example, several companies have indicated considerable interest in JPL's advanced pixel sensor, virtually a "camera on a chip," which is considerably beyond the current state of the art charge-coupled devices. Also, approved last fall for publication in *NASA Tech Briefs* [2], among many other recent disclosures, is the C-Scan, which uses a portable laser ultrasonic and thermographic inspection system, called LUTIS, for nondestructive evaluation of large areas.

Future transfer

In addition to the efforts mentioned above, JPL's Microdevices Laboratory (MDL) (the core to NASA's drive toward the faster, smaller, better concept for future space missions) is fashioning innovative materials and instruments that will aid US competitiveness in world markets. The Micro Weather Station, for example, will someday measure wind, pressure, air temperature, and the dewpoint on Mars. This system also will be used to efficiently monitor Earth's weather; manufactured commercially by a future licensee in private industry.

Some other MDL devices that help scientist explore the physical world include a radiation monitor on a chip, used during the Clementine mission and the Space Technology Research Vehicle mission. This chip effectively monitors the radiation on spacecraft and is potentially very useful in preventing commercial communications-satellite failures.

Near infrared (IR) semiconductor lasers have also been developed at the MDL for on-site gas monitoring. These lasers aid in the development of photochemical models for atmospheric studies, including green house gases, ozone de-pletion and air pollution. Near IR lasers operate at room temperature allowing large cost savings and improved reliability in the miniaturization of spectrometer instruments for space and earth study applications. Added to the other tiny, sophisticated detectors is a Quantum Well Infrared Photodetector that can see infrared radiation of very cold bodies in the upper atmosphere.

NASA has been a prime source of our nation's new technology since its inception in 1958. JPL, along with the other NASA centers, will continue to address and support activities that utilize its various programs' special capabilities to solve problems of national importance and to benefit society.

For further information contact any of the following:

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Technology Utilization:
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References

The following materials were used in the preparation of this article:

[1] J. Haggerty, *National Aeronautics and Space Administration Spinoff 1994*, NASA Office of Space Access and Technology, Commercial Division and Technology Transfer Division, 1994, p. 118.

[2] Jet Propulsion Laboratory Resource Report," *NASA Tech Briefs*, May 1995

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Complex Network Support Facilitates "Live From the Stratosphere"

Pat Kaspar, Contributing Editor, Ames Research Center

Nationwide student interaction with astronomers on the C-141 Kuiper Airborne Observatory (KAO) this fall was made possible due, in part, to a communications effort that involved support from teams at several NASA centers; NASA's Advanced Communications Technology Satellite (ACTS), an experimental satellite developed by NASA to explore advanced communications; several domestic satellites; the KAO aircraft; local and wide area networks; and telephone lines.

This project, known as "Live From the Stratosphere" (LFS), was one of several projects sponsored by the NASA Kindergarten Through Grade 12 (K-12) Internet Initiative, "Sharing NASA With Our Schools", that integrates scientific and engineering pursuits such as high-altitude astronomy, Antarctic biology, and robotics into school curriculum. The LFS project encompassed several elements, such as a connection to the Internet and online services, several television programs broadcast by Public Broadcast System (PBS) stations, three events at Ames Research Center (ARC) with about 120 students attending each event, and a 64-page teacher's guide. Hundreds of sites were able to downlink video, and about a dozen sites (at museums, science centers, and planetariums) were able to uplink live two-way video and audio. For information on LFS access:

http://quest.arc.nasa.gov/interactive.html

"The primary mission of the LFS project," said Marc Siegel, ARC project manager for Sharing NASA, "was to connect schools with a flying astronomer, and to do that, we had to link a flying aircraft with the ground. That mission involved the KAO ground support and flight crews, the KAO education and research team, the ACTS support team at Lewis Research Center, Jet Propulsion Laboratory (JPL) support for the KAO tracking antenna, the NASA K-12 Internet Initiative, the NASA Internet (NI), the NASA Education Office, and many schools and institutions." For a graphic depiction, see the LFS Communications Pathways and the LFS Remote Sites Video Lines Web pages, respectively, at:

http://quest.arc.nasa.gov/lfs/images/com-pathways.gif

http://quest.arc.nasa.gov/lfs/images/remotesites.gif

Interaction between the ground and the aircraft included remote control of various scientific instruments aboard the KAO using Internet connectivity, real time checks of the KAO's equipment performance from the ground, and videoconferencing over the Internet linking the KAO to sites in San Francisco and Chicago. The combination of ACTS and a new steerable antenna made it possible for LFS to accomplish the first live airborne infrared astronomy broadcast. The steerable antenna—the Broadband Aeronautical Terminal custom-built by JPL— automatically tracks ACTS, making it possible to transmit full duplex video, audio, and data between the ground and an aircraft flying anywhere in the Western hemisphere.

Planning for the communications began early in 1995, and in the spring NI engineers went to JPL to accomplish proof-of-concept testing. "We wanted to measure data performance and integrity over ACTS," said A. Lee Wade, NI engineer in charge of the project. "We tested antenna and data performance at the same time by driving an ambulance-sized van equipped with a satellite modem, video compressor/decompressor, data multiplexor, and Internet router around the JPL campus. This was the same equipment that would ultimately be deployed on the KAO. We also tested an Internet videoconferencing tool, CU-SeeMe, over the satellite using Apple Macintoshes. The testing went well, and the JPL-designed mobile satellite antenna delivered better performance than expected."

NI's primary contribution during LFS was connecting the KAO to the Internet. Connectivity was accomplished in the same way that the mobile van communicated with the JPL ground

OUTREACH

The goal of the Science Information Systems Outreach Department is to promote to the general public an understanding of how the results of space science research make significant contributions to American educations systems and to institutions dedicated to improving science literacy. This newsletter provides a vehicle for reporting how applications, hardware, and research and development used for space science research can be adapted for use by teachers and their students and by non-NASA organizations.

station, except that the audio/video and data streams were backhauled via a Program Support Communications Network (PSCN) T1 line (1.544 Mb/s) from the JPL ground station to ARC's main bay where the Internet connection was established. "This was a special T1," said Wade. "It was unique because the 'clocking' that controls the bit rate flow from end to end was taken from the satellite modem on the airplane. Normally the clocking is provided by the T1 network."

The hangar at ARC was connected to the ARC's PSCN gateway with fiber provided by the main bay building and ARCLAN, the Ames local area network, networking staff. PSCN provided the connectivity from ARC to JPL. At JPL a Pacific Bell line was used to connect the JPL PSCN gateway to the satellite ground station. The final segment was provided by ACTS, connecting the ground station to the KAO. Providing the Internet service required the cooperation of the ACTS ground crews at Lewis and JPL, NI, the PSCN at Marshall, ARC and JPL, and the local area networking staffs at ARC and JPL. Providing the PBS video feed required the additional participation of ARC Imaging, Ground Station, and VidNet staffs. "In the Ames hangar," said Wade, "NI provided the local area network infrastructure (ThinNet and 10BaseT connectivity) for the Apple Macintosh computers used by the K-12 project."

The success of LFS can be attributed to many groups and individuals whose work may not be clearly visible, but whose combined cooperation makes such achievements possible.

Information on the upcoming "Live from the Hubble Space Telescope" can be accessed at:

http://quest.arc.nasa.gov/livefrom/hst.html

LFS is part of the "Passport to Knowledge" series and was produced by Geoff Haines-Stiles Productions. Haines-Stiles directed the television coverage of "Live From Other Worlds" in 1993, the first live television broadcast from Antarctica in which a robot under the ice was operated from ARC and "Live from Antarctica" in 1994 that included the first live TV broadcast from the South Pole.

Outreach Activities

Ames Research Center (ARC)

- NI participated in bringing "Live From the Stratosphere" (LFS) to nationwide students. LFS is sponsored by NASA Kindergarten Through Grade 12 (K-12) Internet Initiative, "Sharing NASA With Our Schools", that integrates scientific and engineering pursuits into school curriculum. Hundreds of sites were able to downlink video, and about a dozen sites (at museums, science centers, and planetariums) were able to uplink live two-way video and audio.

Information provided by Pat Kaspar, Contributing Editor, ARC

Jet Propulsion Laboratory (JPL)

- Mars Explorer Program (MEP) educational advisory board held a workshop in December for K-12 teachers to assist in the development of classroom activities and curricula.
- JPL's Public Service Office is assisting the Boston Museum of Science in finding scientists who are willing to take part in a pen pal program called Science-By-Mail. This program pairs youngsters, grade four through nine, and volunteer scientist pen pals and sends the students two science challenge packets per year. The packets contain materials and procedures for hands-on experiments in the categories of 1) science of sports and 2) planetary science. The youngsters send their creative solutions to their assigned scientist who respond with encouraging feedback.

Information excerpted from the JPL Universe, NASA press releases, and MEP Significant Events.

Goddard Space Flight Center (GSFC)

- The GSFC-managed Minority University-Space Interdisciplinary Network (MU-SPIN) Project conducted Network Regional Training Workshops at the following newly formed Network Resources and Training Sites (NRTS):
  - Elizabeth City State University, Elizabeth City, NC
  - Morgan State University, Baltimore, MD
  - Prairie View A&M University, Prairie View, TX
  - South Carolina State University, Orangeburg, SC
  - Tennessee State University, Nashville, TN
  - The City College of New York, New York, NY
  - The University of Texas at El Paso, El Paso, TX

  Attendance at each of the Workshops averaged approximately 80 faculty, technical staff, and students from five Historically Black Colleges and Universities and Other Minority Universities in the NRTS' region. The workshops included presentations and online demonstrations of resources and services on the Internet, basic operation and management of TCP/IP networks, and the MU-SPIN-developed Network Startup Kit.
- The GSFC Information Infrastructure Technology and Applications' K-12 Program, in cooperation with the GSFC Education Office, placed Internet access equipment and augmented staff in GSFC's teacher resource laboratory (TRL) for network media support. The resulting Model TRL holds training sessions for area teachers on Macintosh computers, the Internet, and the World Wide Web (WWW). The Model TRL took center stage during the GSFC TRL's 10th anniversary and renovation celebration held in Nov.
- The High Performance Computing Center (HPCC) conducted the fifth NASA Summer School in High Performance Computational Physics to train the next generation of computational scientists in the use of HPCC technologies. Sponsored by GSFC and organized by the University Space Research Association, the summer school provides an intensive lecture series in computational physics each July for 16 graduate students from across the country. Experienced computational physicists present lectures on advanced topics in computational fluid dynamics, while vendors of scalable parallel computer systems (this year the Cray T3D and the MasPar MP-2) hold lab sessions on developing software for their machines. The program is geared to computational scientists with some interest in physics, astronomy, meteorology, and oceanography who are working toward PhD's in the Earth and space science disciplines.

Information provided by Judy Laue, Contributing Editor, Hughes STX, GSFC

General

- NASA and the US Geological Survey (USGS) recently released the Planetary Photojournal, an extensive collection of images of the planets produced by the US space program. The Photojournal includes images currently residing at the Jet Propulsion Laboratory and the USGS in Flagstaff, Arizona. It is accessible on the Internet via the WWW and features both thumbnail and browse-size versions of the images and mapping data, and allows user-friendly digital downloading in a variety of formats. The new system also provides links to other space image data collections and other related-interest sites, such as space mission home pages. Viewing is available at either of two sites:

  http://www-pdsimage.jpl.nasa.gov/pia/
  http://www-pdsimage.wr.usgs.gov/pia/

Information excerpted from NASA press release 96-21, February 1, 1996

- Students in K-12 had the opportunity to work alongside some of America's foremost astronomers doing real science observations using NASA's Hubble Space Telescope. The resulting observations were featured in a live interactive telecast on NASA TV and on public television in March and April of this year. The students selected Neptune and Pluto for observation. Mission planners then developed detailed plans, which the student" co-investigators" followed via the Internet. They also interacted with astronomers via the Internet. The students were featured on "Live from the Hubble Space Telescope: Making Your Observations" on March 14 and on "LIve from the Hubble Space Telescope: Announcing Your Results" on April 23. This project was part of the Passport To Knowledge program that is sponsored by NASA, the Space Telescope Science Institute, the National Science Foundation, and public television. For information on this project, access:

http://quest.arc.nasa.gov/livefrom/hst.html

Information excerpted from NASA press release 96-34

- Mission to Planet Earth program has awarded a $500,000 grant to the Smithsonian Institution's national Museum of Natural History to support planning for a new museum exhibition hall titled "Forces of Change". This exhibition hall will feature a series of regional case studies demonstrating the ways in which the Earth's environment is changing and how humans affect or are affected by these processes. Initial case studies on the Antarctic polar region, the Hawaiian islands, the Chesapeake Bay estuary, and the Great Plains grasslands will offer museum visitors interactive, state-of-the-art displays on how natural forces influence their daily lives.

Information excerpted from NASA press release 96-32

Public Invited to "Fly Your Name to Saturn"

A high-tech equivalent of a message in a bottle will carry the signatures of thousands of vicarious space explorers to Saturn in1997. The signatures will be on board the Cassini spacecraft via a CD-ROM or other digital media. To achieve this, volunteer members of The Planetary Society, Pasadena, California, will scan submitted signatures. The scanned digital data will then be loaded onto the digital media, which will be mounted onto the Cassini spacecraft during its final assembly at Kennedy Space Center in Florida.

Cassini, scheduled for launch on October 6, 1997, is a joint mission of NASA, the European Space Agency, and the Italian Space Agency. It will send an atmospheric probe named Huygens to the surface of Saturn's moon Titan. The Cassini spacecraft will orbit Saturn for four years, gathering data on Saturn, its rings, magnetic environment, and moons. The Cassini home page, which offers a wide variety of information about the mission and the planet Saturn, can be accessed at:

http://www.jpl.nasa.gov/cassini/

Earlier NASA spacecraft such as Viking, Magellan, and Galileo also carried thousands of signatures on other media, but Cassini will be the first to utilize modern digital storage technology. The disc is expected to hold about a million names and should survive well beyond the duration of Cassini's 11-year mission.

"The people who have already sent in signatures think this is a wonderful idea," said Suzanne Barber, administration manager of the Cassini Program. "School teachers love it — it just seems to capture their students' imaginations, and it offers them a feeling of immortality to be able to send their names into space."

To participate, signatures should be sent on a plain postcard. Multiple signatures per postcard are acceptable. Names will be accepted until January 1, 1997, or until the CD-ROM is full. Postcards should be sent to:

Suzanne Barber
MS 264-441
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109

Electronic mail transmittals cannot be accepted, and confirmation will be provided only to those who enclose a self-addressed, stamped envelope. Excerpted from NASA press release 96-91 written by Stephanie Zeluck, Jet Propulsion Laboratory.

The Multimission VICAR Planner: A Knowledge-based System for Automated Image Processing

Steve Chien, Darren Mutz, and Richard Doyle, Information Systems Technology Section, and Helen Mortensen, Sue LaVoie, and Bill Green, Science Data Processing Section, Jet Propulsion Laboratory

In recent times, improvements in spacecraft imaging hardware have caused a massive increase in the amount of scientific data and in the variety of science data products. Simultaneously, increased sophistication of instrumentation and image processing algorithms has greatly increased the knowledge required to prepare image data for analysis. While improvements in data storage and database technology have allowed physical access to the vast amounts of space-related data, preparing and processing available scientific data has become increasingly labor and knowledge intensive.

Development of general purpose data processing languages and interfaces can mitigate this data access, preparation, and analysis problem. These languages and interfaces allow you to access and process data within a common environment. The Video Image Communication and Retrieval (VICAR) environment—this name is somewhat misleading as VICAR is used to process a considerable amount of non-video image data, such as MAGELLAN synthetic aperture radar data—is a major constituent of the Jet Propulsion Laboratory's (JPL's) image processing capability. VICAR provides a standard interface to allow you to retrieve data and apply sophisticated data processing algorithms. VICAR, whose principal focus is planetary instrument processing, supports instruments for JPL flight projects including Voyager, Viking, Magellan, Galileo, Mars Pathfinder and Cassini. VICAR possesses many unique data processing capabilities relating to these image sources. In addition to JPL, VICAR users include universities, the military, research institutions, aerospace corporations, commercial companies, and Home Institution Image Processing Subsystem (HIIPS) sites with over 100 users.

VICAR processing

VICAR allows individual processing steps (called VICAR programs) to be combined into more complex image processing scripts called procedure definition files (PDFs). As one of their primary duties, JPL analysts construct PDFs to achieve tasks such as image correction, image enhancement, construction of mosaics, creation of movies, and rendering of objects. For example, Figure 1 depicts a code fragment that performs portions of image navigation manually for Galileo images (this code was generated by the multimission VICAR planner (MVP)). The higher level conceptual steps are shown on the left and the corresponding VICAR code appears on the right. In this case, the tasks being accomplished are: acquiring initial navigation information, constructing initial overlap pairs, refining initial overlap pairs, checking for a previous tiepoint file, manually generating or refining tiepoints, and constructing the OM matrix (the planet-to-camera coordinate transformation matrix) for image navigation. Here the overall user goal is to construct a mosaic of several raw image files. The other subgoals (and steps) are necessary to support this goal due to the dependencies of VICAR and image navigation.

In order to fulfill operational science analysis requests for image processing, analysts use their knowledge of the processing steps and processing program requirements to construct VICAR programs. This process involves determining the relevant programs to use, their order of execution, and their respective parameter settings.

Unfortunately, manual construction of VICAR procedures is both labor and knowledge intensive. This is due in part to the complexity and the amount of program knowl-

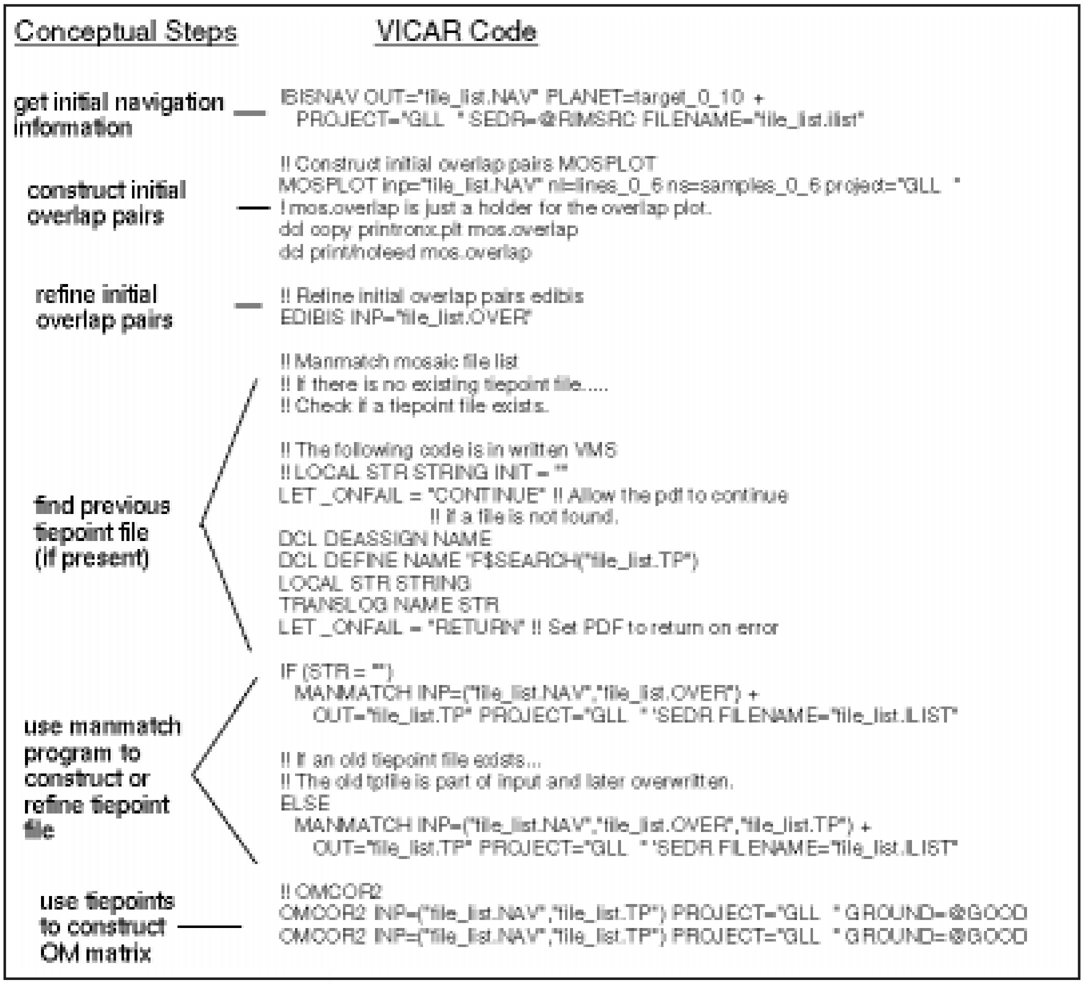

Figure 1. VICAR code fragment

edge relevant to the task, as well as to the many interacting problem goals. Generation of a highly complex VICAR procedure may take up to months of an analyst's time. While developing such a procedure, analysts draw on their knowledge of:

- instrument characteristics, performance and calibration
- image processing and image processing programs (as of 8/95 there were 300-400 VICAR programs, some having 10s of options)
- database organization and database label information in order to understand the state of relevant data
- the VICAR programming language to perform the desired image processing tasks

One difficulty facing analysts is the diversity of knowledge required to produce expert VICAR procedures. While expert analysts may be widely diverse in their knowledge of VICAR, the vast majority of users are novices in one or more aspects. For example, a university user may know a great deal about the science behind the imaging and the theory behind the processing steps, but may know little about the underlying assumptions of the implementation of the processing steps or of VICAR itself. Similarly, programmers who write processing programs may be very knowledgeable about their particular programs but may experience difficulty in writing a VICAR procedure to test the programs. Unfortunately, this situation increases the load on experts who must spend a significant amount of time assisting those less knowledgeable. This great need for VICAR knowledge exists because of the significant time it takes to become proficient in multiple aspects of VICAR, often several years to become a VICAR expert.

The MVP

The MVP [1,2] partially automates generation of image processing procedures from user requests and a knowledge-based model of an image processing area using Artificial Intelligence (AI) automated planning techniques [5,9,10]. An AI planning system uses:

- a model of possible actions that can be used to change the current state
- a specification of the current state
- a goal specification (a description of the desired state)

to determine the actions necessary and the order of occurrence, to change the current state into the goal state. In the case of VICAR image processing, the actions are VICAR image processing programs, the current state is the current state of the image files of interest, and the specification of the desired state corresponds to your image processing goals. By partially automating the filling of basic science image processing requests, image processing request turnaround time is reduced, the analysts' time is freed for more complex and challenging science requests, and the workload is reduced. As an additional benefit, encoding valuable image processing knowledge in MVP allows knowledge to be retained by institutions, rather than being lost when analysts leave or retire.

From a technology standpoint, MVP is significant in several respects. First, MVP integrates multiple planning approaches to most naturally represent the constraints inherent in this area of image processing and the problem-solving methods of human experts. Second, MVP uses novel methods to represent and reason about VICAR program option constraints. From an applications standpoint, MVP is significant in that is a successfully deployed AI planning application.

The MVP architecture

Figure 2 depicts the overall architecture for the MVP system. You input a problem specification consisting of processing goals and image information using a menu-driven graphical user interface. These goals and image information are then passed to the decomposition-based planner. The decomposition planner uses decomposition rules to implement two conceptual types of planning. First, the decomposition-based planner uses image processing knowledge to classify the overall problem type, which the user has specified in a process called skeletal planning [5]. Second, the decomposition planner uses this classification to decompose the problem into smaller subproblems in a process called hierarchical planning [10]. The subproblems produced by the decomposition process are then solved by operator-based planning [9], in which a planner uses a description of possible actions (in this example image processing steps) to solve subproblem goals as indicated by the problem decomposition. The resulting plan segments are then assembled using constraints derived in the decomposition process. At this point, the resulting plan is used to generate an actual executable VICAR PDF using conventional macro expansion techniques.

MVP uses both decomposition and operator-based planning techniques for two reasons: reduced complexity and user understandability. The decomposition approach is needed for controlling the computational resources required by plan generation. The image processing scripts MVP is designed to generate can be of considerable length (up to 100 steps) and each step (or VICAR program) can involve reasoning about numerous complex effects. For this reason, it is computationally unfeasible to use strictly operator-based planning approaches. Coupling operator-based planning techniques with the decomposition planning paradigm enables MVP to reduce the large planning problems associated with image processing tasks into several smaller, more manageable subproblems.

MVP also uses decomposition-based planning for reasons of user understandability. Even if a purely operator-based planning approach were able to generate plans to solve the VICAR problems, these plans would be difficult for image analysts to understand because analysts do not necessarily consider an entire image processing problem all at once. Typically, analysts begin by classifying the general problem at hand into one of a general class of problems, much the same way that MVP addresses the problem through decomposition-based planning.

An illustrative example

As an example, a real world application of MVP is presented, where the image processing goal consists of correcting and mosaicking three Galileo image files. These images (Figure 3, left side) are of planet Earth, specifically northeastern Africa and Saudi Arabia. Errors in the compression and transmission of the data from the Galileo spacecraft to receivers on Earth has resulted in a fair number of missing or noisy lines in the images. These anomalies need to be corrected in the finished image and

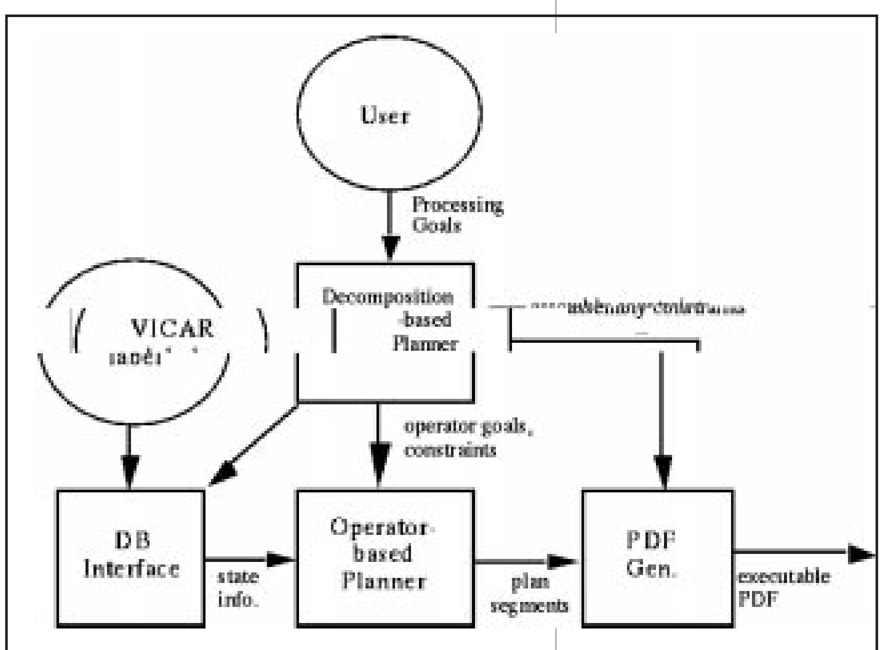

Figure 2. Overall architecture for the MVP system

also map projected, in order to correct for the spatial distortion that occurs when a spherical body is represented on a flat surface.

At this point, you can describe the image processing goal to MVP through the graphical user interface. Most of the image processing options of interest translate to toggle buttons on the interface. A few options require entering some text, usually function parameters that will be included as literals in the appropriate place in the generated VICAR script.

After the image processing goals have been specified, MVP is ready to automatically generate the VICAR script. The image processing goals described by the user are broken down and achieved by the goal decomposition planner and the operator-based planner. This process of goal achievement is shown in graphical format in Figure 4. In this example, the goals from the decomposition are listed at the top of the graph: compute-om-matrix and update-archival-sedr. The planner has decided to use the OMCOR2 operator to achieve the compute-om-matrix goal. The planner has also decided to use the MANMATCH program to achieve the tiepoint-file precondition for the OMCOR2 operator. (Note that this subgoal graph corresponds to the code shown earlier in Figure 1). After this process has terminated, the method the planner derived for achieving the image processing goals is translated into the VICAR code that is used to construct the image processing script. This script, when run, performs the desired image corrections and constructs a mosaicked image of the three input files. The finished result of the image processing task is shown in Figure 3 (right side). The three original images now appear as a single mosaicked image, map projected with missing and corrupted lines filled in.

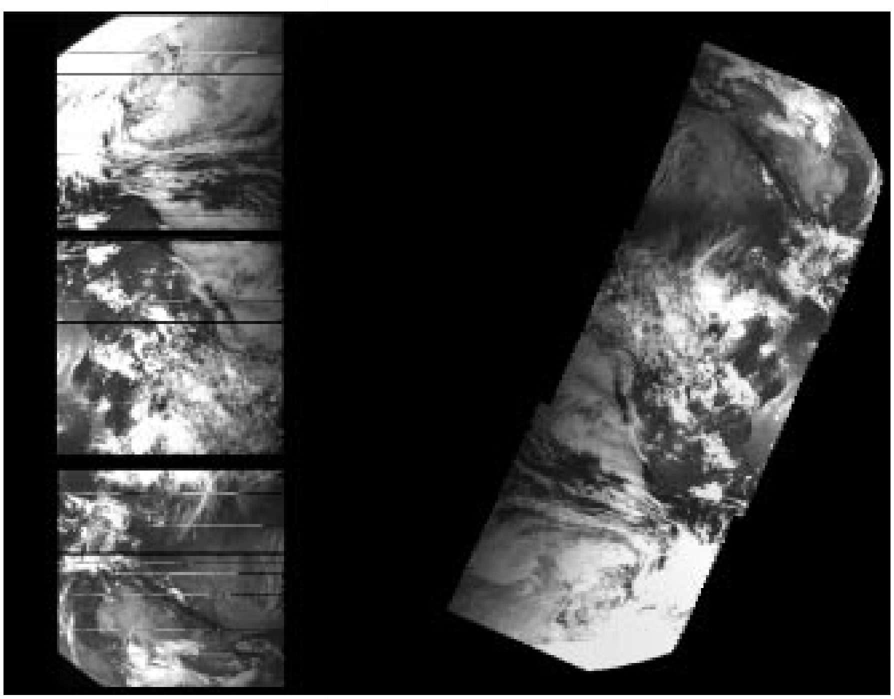

Figure 3. Anomalies manifest themselves in images sent from the Galileo spacecraft

The current state of MVP

MVP3.0s is implemented in C and runs on Sun SparcStations under Solaris. MVP is currently operational and available for use by analysts at JPL's Multimission Image Processing Laboratory for radiometric correction, color triplet reconstruction, and mosaicking with relative or absolute navigation, registration, and simple filtering and stretching tasks. For these tasks MVP reduces the time to generate an initial PDF for an expert analyst from half a day to 15 minutes and reduces the time for a novice analyst from several days to 1 hour. This represents over an order of magnitude in speedup. The quality of the PDFs produced using MVP is comparable to the quality of completely manually derived PDFs. In some cases parameters need to be modified subjectively or goals reconsidered in context (this is why it takes 15 minutes to construct the PDF using MVP rather than the 1-2 minutes for a single run of MVP).

Current efforts focus on fielding a version of MVP for a planetary geology group at the department of Geology at Arizona State University. This version of MVP would be used primarily for map projection and detection and attribute measurement of geological features. Finally, the MVP planning engine has been applied to the problem of generating Deep Space Network Antenna Operations procedures [4].

Related work can be broadly classified into: related image processing languages, related automated image processing work, and related AI planning work. There are many commercial and academic image processing packages such as IDL, Aoips, and Merlyn. Generally, these packages have only limited ability to automatically determine how to use different image processing programs or algorithms based on the problem context (e.g., other image processing goals and initial image state). These packages only support such context sensitivity for a few pre-anticipated cases. In contrast, MVP uses a general model of the image processing tasks expressed in task decomposition rules and planning operators and can handle all cases covered by this model. Perhaps the most similar planning and image processing system is COLLAGE [6]. The COLLAGE planning system differs from MVP in that COLLAGE uses solely the decomposition approach to planning. COLLAGE differs from MVP in the applications sense in that it focuses primarily on Earth imaging applications in the Khoros environment, where MVP has focused on planetary applications in the VICAR environment.

MVP represents a significant contribution to both planning technology and planning applications. MVP makes two novel contributions to planning technology. First, MVP integrates decomposition-based (also called hierarchical task network) and operator-based approaches to more closely model how human experts solve image processing problems. Second, MVP uses an explicit constraint model to efficiently search among operator effects (that correspond to VICAR program options). MVP makes a significant contribution to applications in planning in that it is a successfully deployed planning application that significantly reduces the effort to perform a complex class of image processing tasks.

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References

The following reference materials were used in the preparation of this article:

[1] S. Chien, "Using AI Planning Techniques to Automatically Generate Image Processing Procedures: A Preliminary Report," *Proceedings Second International Conference on AI Planning Systems*, Chicago, IL, June 1994, pp. 219–224.

[2] S. Chien, "Automated Synthesis of Image Processing Procedures for a Large-scale Image Database," *Proceedings First IEEE International Conference on Image Processing*, Austin, TX, November 1994, Vol. 3, pp. 796–800.

[3] K. Erol, J. Hendler, and D. Nau, "UMCP: A Sound and Complete Procedure for Hierarchical Task Network Planning," *Proceedings Second International Conference on AI Planning Systems*, Chicago, IL, June 1994, pp. 249–254.

[4] R. Hill, S. Chien, C. Smyth, and K. Fayyad, "Planning for Deep Space Network Operations," *Proceedings 1995 AAAI Spring Symposium on Integrated Planning Applications*, Stanford, CA, March 1995, pp. 51–56.

[5] Y. Iwasaki and P. Friedland, "The Concept and Implementation of Skeletal Plans," *Journal of Automated Reasoning 1, 1* (1985), pp. 161–208.

[6] A. Lansky, M. Friedman, L. Getoor, S. Schmidler, and N. Short Jr., "The Collage/Khoros Link: Planning for Image Processing Tasks," *Working Notes 1995 AAAI Spring Symposium on Integrated Planning Applications*, March 1995, pp. 67–76.

[7] A. Lansky, "Action-based Planning," *Proceedings Second International Conference on AI Planning Systems*, Chicago, IL, June 1994, pp. 110–115.

[8] S. LaVoie, D. Alexander, C. Avis, H. Mortensen, C. Stanley, and L. Wainio, *VICAR User's Guide, Version 2*, Jet Propulsion Laboratory Internal Document D-4186, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 1989.

[9] J. S. Pemberthy and D. S. Weld, UCPOP: "A Sound Complete, Partial Order Planner for ADL," *Proceedings Third International Conference on Knowledge Representation and Reasoning*, October 1992.

[10] M. Stefik, "Planning with Constraints" (MOLGEN: Part 1), *Artificial Intelligence 16, 2* (1981), pp. 111–140.

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Accomplishments

Information Systems Program Highlights

Major accomplishments achieved by NASA's Information Systems Branch (Code ST) are highlighted below. They cover work performed from December 1995 through February 1996, and reflect the combined efforts of many people.

Ames Research Center (ARC)

NASA Internet—Christine Falsetti

- The Space Bridge to Russia (SBR) team coordinated a telemedicine demonstration in December for the NASA Chief Information Officer, John Lynn. The demonstration included postscript files that were posted to the Multicast Backbone whiteboard. A live "In Person" session with Lewis Research Center (LeRC) was conducted with two-way video, whiteboard, and audio. LeRC downloaded x-ray images that are representative of information that will be used in the actual SBR project.
- The team demonstrated Video On Demand (see *Science Information Systems Newsletter*, Vol III, 1995) using MPEG2 over an asynchronous transfer mode (ATM) link between ARC and San Diego at the Supercomputing '95 conference. The complete demonstration showed interoperability between platforms and the ability to use off-the-shelf products that can be integrated and transferred to other operational tasks.
- The NI-Earth Observing System (EOS) Networking Project coordinated the initial development of concepts and planning for the June 1996 Global Observation Information Network Workshop to be held in Tokyo, Japan. The Workshop will consist of seminars and demonstrations related to network objectives, including data policies and World Wide Web (WWW) server development for global observation data, network security, technology transfer, policy products for decision makers, and multimedia interactive technology.
- Ni engineering staff are progressing in their support of the US Agency for International Development program to extend its virtually private, fully integrated, low cost, TCP/IP-based internetwork via satellite (Very Small Aperture Satellites/Time Division Multiplex Access) to its missions around the world. Satellite downlink sites have been selected, and installation and commissioning of the new sites continues as scheduled.
- NI Requirements Managers and the NI Project Manager participated in end-of-year meetings with requirements validators at NASA Headquarters to review the *NI Annual Project Report FY95*. This report includes an executive overview of FY95 activities; project descriptions and status for select projects; and high-level project-by-project timelines, mapping requirements implementation plans to significant project milestones. To request copies of the report, contact Debbie Roberts at:

  droberts@nsipo.nasa.gov

- NI supported 16 exhibitors, 31 electronic poster sessions, and the email booth at the American Geophysical Union meeting in San Francisco, California, in December, 1995. At the American Astronomical Society meeting in San Antonio, Texas, in January, 1996, NI supported 15 network connections to exhibitors booths, enabling demonstrations of such network-accessible tools as Netscape, and supported the email terminals. NI also demonstrated network tools at both conferences.

Goddard Space Flight Center (GSFC)

Computer Networks and Communications Branch (CNCB)—J. Patrick Gary

- The Computer Networks and Communications Branch (CNCB) extended the Earth System Science Network's (ESSN) ATM-based 310 Mbps backbone to GSFC Building 21 and interconnected Building 21 in an ATM network ring configuration with Buildings 22 and 28. The CNCB installed an ATM-based firewall in GSFC Building 1 to enable a high performance interconnection between the ESSN and the 155 Mbps NASA Research and Education Network (NREN)

- Supercomputers from around the country sent data over the CNCB-supported high performance, ATM-based Information Wide Area Year (IWAY) network for advanced graphics demonstrations at Supercomputing ’95 (SC95) held in San Diego. The CNCB enabled a 155-Mbps IWAY interconnection between the NREN and the Advanced Technology Demonstration Network (ATDNet) for a demonstration between computers at SC95 and the Enterprise Room at the Advanced Research Project Agency’s headquarters, VA. Also, in collaboration with Bell Atlantic, the CNCB extended the ATDNet and IWAY to the University of Maryland Institute for Advanced Computer Studies Parallel Processing Laboratory at the University of Maryland, College Park. This IWAY/NREN/ATDNet extension enabled access to an National Science Foundation-funded Grand Challenge spherical database prototype that stores/retrieves Level 1 global satellite imagery running on an IBM SP2.
- The CNCB completed a seamless interconnection between the NREN and the ATM-based networks of the ARPA-funded Multidimensional Applications and Gigabit Internetwork Consortium (MAGIC)/Advanced Communications Technology Satellite (ACTS) ATM InterNetwork. The CNCB enabled 20 Mbps memory-to-memory and 12 Mbps file-transfer-protocol (FTP) data exchanges over the 45 Mbps ATM end-to-end link between EROS Data Center (EDC) and Moderate Resolution Imaging Spectrometer Team computers in GSFC Buildings 22 and 28. The CNCB demonstrated via this link that the use of extended TCP windows can improve throughput performance by an order of magnitude, i.e., from ~3 to ~30 Mbps in memory-to-memory tests and from ~2 to ~22 Mbps using FTP. In the future, this link will be used for network tests with the ACTS-based connection planned between GSFC and the MAGIC network. The link will also be used by EDC for transferring 620 GB of Advanced Very High Resolution Radiometer data for EOS Data and Information System ATM Network Applications Prototyping.

Mass Storage and Scientific Computing Branch (MSSCB)—Nancy Palm

- The NASA Center for Computational Sciences (NCCS) is tripling the computing power available to the user community by switching from a CRAY C90 supercomputer to a cluster of three CRAY J932 systems that will provide 96 cpu’s, 19.2 peak GFLOPS, and 12 GB of main memory. This equipment will enable the NCCS to move its production computing to a predominantly parallel environment. A Cray J916/16 processor is in place for testing of critical codes by the user community. A second Cray J932/32, which has been delivered and is being configured for the entire user community, will replace the Cray C98 processor in the near future.
- Effective November 2, 1995, System Engineering and Security Inc. (SES) began providing support to maintain and operate the Space Data and Computing Division’s NCCS computational facility. SES replaced KenRob, the former contractor.
- Members of the Mass Storage and Scientific Computing Branch (MSSCB) provided technical leadership and support to the development of the SEWP II RFP. Five draft versions of the Request for Comment have been released via the WWW, and over 1,000 comments have been received to date.
- The latest release of Convex/UniTree 2.0+ (aka RedOak) was tested in a live production environment. Problems with tape process handling forced the NCCS to revert to UniTree 1.7.6, the previous version.

High Performance Computing Branch (HPCB)—Jim Fischer

- The Earth and Space Science (ESS) Project completed evaluation of proposals received in August in response to the High Performance Computing Center (HPCC) Cooperative Agreement Notice

(CAN) issued by GSFC last May (see "Accomplishments," *NASA Science Information Systems Newsletter*, Issue 36, July 1995). This CAN solicited two types of proposals: (1) teams of Earth and Space Science Grand Challenge Investigators, and (2) advanced scalable parallel computing testbeds capable of supporting the Grand Challenge problem research. Announcement of selection has been delayed until NASA HPCC receives a budget from Congress.

- The FY95 Annual Report of the HPCC/ESS Project is available via the WWW at:

  http://sdcd.gsfc.nasa.gov/ESS/annual.reports/ess95contents/ess95.html

- Software submission to the National HPCC Software Exchange (NHSE) is now open to all. Access http://www.netlib.org/nhse/software_submit/ for a submission form. In 1994, GSFC awarded a grant to the Center for Research in Parallel Computing at Rice University, Ken Kennedy/PI, to create the NHSE (see "Accomplishments," *NASA Science Information Systems Newsletter*, Issue 34, Dec. 1994) to facilitate development and distribution of software-enabling technologies for high-performance computing. During the summer of 1995, the NHSE Investigators evaluated results from the trial run of the NHSE software submission and review process; their evaluation is posted at:

  http://www.netlib.org/tennessee/ut-cs-95-312.ps

  The NHSE is located at:

  http://www.netlib.org/nse/home.html

  It is supported by ARPA, the Department of Defense, the Department of Energy, the Environmental Protection Agency, NASA, NIST, NSA, and NSF.

Scientific Applications and Visualization Branch (SAVB)—Horace Mitchell

- Global Learning and Observations to Benefit the Environment (GLOBE) operations will be privatized by FY97 (GLOBE HQ will select a company by Spring 1996). Until then the GLOBE design and development will continue at GSFC.
- Scientific Visualization Studio (SVS) personnel produced several videos that dramatically illustrate science performed at GSFC and other institutions.
- Stephen Maher expanded the repertoire of SVS virtual reality tools for scientific visualization by obtaining a copy of the Virtual Wind Tunnel from ARC. The tool primarily visualizes computational fluid data but also can visualize the generic 3 D data encountered in the Earth sciences. An ARC/GSFC collaboration is in place that makes GSFC a testbed for the tool.
- Andrea Hudson and Dennis Morrow (CRI) presented the two day poster session "Estimation Algorithm for Satellite Altimetry Data on the Cray T3D" by Vara Ramakrishnan/University of California at Irvine (1995 VSEP student), Hudson, Morrow, and Nikolaos Pavlis/HSTX at SC95. The session showed that ocean tidal model problems scale well on the Cray T3D parallel architecture.

Jet Propulsion Laboratory

Data Distribution Laboratory (DDL)—Mike Martin

- The DDL supported the production of the TOPEX/Poseidon Information CD-ROM, *Perspectives on an Ocean Planet*, that describes the mission from conception through operations. The CD-ROM provides seven chapters with 34 Quicktime movies and 44 images with captions. The DDL had two objectives for this project: to provide a comprehensive story about the mission and to demonstrate the effective use of multimedia segments to describe complex instruments and data sets.

Navigation Ancillary Information Facility (NAIF)—Chuck Acton

- NAIF introduced the SPICE Database Kernel, an E-Kernel subsystem that deals with Events data. Scientists will use these events data to better understand the exact performance of science instruments, the host spacecraft, and the mission's ground system.

Exploiting Web Technology To Make Data Finding and Access Easier

Jason Mathews, Computer Engineer, and Syed Towheed, Systems Programmer, National Space Science Data Center, Goddard Space Flight Center

The World Wide Web (WWW), which was originally conceived for document delivery, has evolved into a medium supporting interactive data visualization and distribution. Two Web-based data systems, OMNIWeb and COHOWeb, have been developed at the National Space Science Data Center (NSSDC) at Goddard Space Flight Center for providing enhanced access to scientific data. Using only freely available WWW browser software, a researcher can not only retrieve data but also perform interactive visualization of the data through a simple point-and-click interface.

Advantages of WWW technology

The WWW has the technology to provide visualization and browsing of data over standardized communication protocols. Web-based systems can be built rapidly since no resources must be directed to developing the client and server software or network protocols because of its interoperable multimedia graphical user interface and choice of several non-proprietary protocols. In addition, the hypertext feature of the WWW can be exploited to reduce development time and couple metadata (i.e., information about the data) with the system.

There are several compelling advantages in using the WWW to provide access to data. First, the browser software needed to access a WWW site is freely available for almost all computing platforms. The server software required to “serve” data is also freely available. Second, the WWW uses an open non-proprietary network protocol while the browser software supports additional network protocols such as file transfer protocol, Telnet, Gopher, News, the Wide Areas Information System, etc. Third, the WWW supports multimedia; textual information can be served side by side with images, video, and audio. In fact, WWW browsers can be easily extended to support almost any digital media type. Fourth, the WWW has the powerful hypertext feature that allows developers to link various pieces of information and data into an information “space.” Fifth, WWW browsers are very simple to use requiring no special knowledge (i.e., you can simply point and click to retrieve information or perform functions). Lastly, the language used to develop WWW content is easy to learn. These advantages allow information providers to build, rapidly and economically, multimedia data and information systems that are easy to use.

The OMNIWeb data system

The NSSDC OMNIWeb data system was created in late 1994 for enhanced access to the OMNI dataset, which consists of one-hour-resolution, near-Earth solar wind magnetic field and plasma data; energetic proton fluxes (1-60 MeV); and geomagnetic and solar activity indices. The OMNI data have been network-accessible via the NSSDC Online Data and Information Service, without graphical analysis capability, for several years now. OMNIWeb introduced the enhanced capabilities of visualization, listing, subsetting, and data conversion through the WWW. Interactive visualization of the data is supported through 2D time series plots that are dynamically generated as GIF or PostScript files using the Interactive Data Language. This visualization feature aids in finding trends and isolating areas of interest in the data. After browsing the data, you have the ability to generate ASCII listings, subsetted files, or raw binary files for further analysis.

OMNIWeb addressed the need of researchers to access a single data set with visualization and retrieval capabilities over the Web. It was designed with a generic framework in mind to support any data set conforming to the NSSDC common data format (CDF) data standard. An open architecture is developed on top of this data standard that provides a transparent machine-independent application programming interface (API) to store, manipulate, and access multidimensional data sets. Data stored in CDF are self-describing such that a CDF application can provide generic data access to any CDF data file. The access tools for listing, converting, subsetting, and plotting the CDF data were not designed for any specific CDF but to any time-ordered CDF with a minimum set of metadata attributes that describe the data to access. Furthermore, the software tools developed for OMNIWeb have been reused in another data system, COHOWeb. Within the NSSDC Web server the same data access tools are shared by both OMNIWeb and COHOWeb, which have different underlying data sets.

From OMNIWeb to COHOWeb

The COHOWeb system was built shortly after OMNIWeb and provides similar access to the Coordinated Heliospheric Observations (COHO) data, which consist of hourly to daily averages for heliospheric key parameters selected from spacecraft ephemerides and science experiment measurements of interplanetary solar wind plasma, magnetic fields, and energetic particles. Data sources include historical and on-going deep space missions such as Ulysses, Helios 1 and 2, Pioneer 10 and 11, Pioneer Venus Orbiter (Pioneer 12), and Voyager 1 and 2.

COHOWeb reuses many of the ideas and the software from OMNIWeb. However, COHOWeb represents a more evolved and generalized implementation of a WWW-based data system in that multiple data sets are supported through a single interface that is generated dynamically from the data themselves. COHOWeb is easily expandable since data can simply be “plugged” into the system without changing the underlying software. The system can also be reused to provide access to other data as well, a feature that has been requested by a number of NASA projects and universities for building similar data systems.

NSSDC provides “What’s New” pages from the OMNIWeb and COHOWeb home pages to help keep users informed as to what has been recently changed or added. Contact information is provided at the bottom of every page, and there is a feedback mechanism to allow users to communicate directly with the developers. Much feedback has been received, and many of the requests for enhancements, such as some advanced customization options (e.g., PostScript output, symbol and character sizes, logarithmic axes scaling), have been implemented.

OMNIWeb and COHOWeb represent a framework from which to model data systems providing interactive access to data via the WWW. These systems provide not only access to large amounts of science data but also allow you to perform various operations on the data.

Future developments

Depending on the nature of the data, generating 3D visualizations of data can aid the researcher in interpreting the data. Conceivably, more functionality, like dynamically creating a 3D representation of the data in the Virtual Reality Modeling Language, could be added to these data systems. Some work has been done to evaluate its feasibility. You may view Virtual COHO, at:

http://coney.gsfc.nasa.gov/Mathews/vrml/vr-coho/coho.html

Other visualizations could produce audio and video from the data. An open system should allow various visualization operations to be added to the appropriate data formats with a set of options to control the visualization.

Access information

For access to these systems and the corresponding data, OMNIWeb and COHOWeb are available, respectively, over the WWW at:

http://nssdc.gsfc.nasa.gov/omniweb/ow.html
http://nssdc.gsfc.nasa.gov/cohoweb/cw.html

For further information contact Jason Mathews at:

mathews@nssdc.gsfc.nasa.gov

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Many thanks to Barry Jacobs for his ideas about electronic information management that have been applied to COHOWeb and OMNIWeb; Joe King, John Cooper, and Natalia Papitashvili for COHO data; Joe King for OMNI data; and to the other staff members at the NSSDC.

An Old Dog Learns New Tricks

Gary Spradlin, Voyager Project, Jet Propulsion Laboratory

For twenty years the Voyager Project has engendered enthusiastic public support as a result of it's twin spacecraft flybys of the gas-giants Jupiter and Saturn, and subsequent flybys of Uranus and Neptune by Voyager 2. Now flying a low-drama extended mission, the project has had to become more resourceful in finding ways to sustain public support of and interest in Voyager. Like many organizations, the Voyager Project is using the Internet and the World Wide Web's (WWW) graphical capabilities as public outreach tools to provide information about the current mission of the Voyager spacecraft, as well as to provide a historical perspective of Voyager's contributions to science. The project's intent is to provide an interesting and educational WWW site for use by the general public and, in particular, science students and educators.

Unique features

The Voyager Project home page (Figure 1), a work in progress, has some unique features. Besides links to mission and science information and select photographs from each planetary flyby, there is a clickable spacecraft map. By selecting a location on this map, you may link to descriptions of various subsystems and science instruments, or to Voyager's *Message to the Universe* (Figure 2), as carried by the "Golden Record" on-board each of the Voyager spacecraft. The Golden Record link presents not only a text description, but also provides online access to 116 images, greeting messages from Earth in 55 different languages, 39 different sounds of Earth (whales, crickets, jet engines, etc.), and 22 musical selections (classical, folk, and rock-and-roll). Some items on Voyager's Golden Record are still protected by US copyright laws and are not available on the home page at this time. As approvals are obtained, these currently unavailable items may be included at a future date.

For serious researchers, Voyager's Home Page provides a bibliography of scientific publications generated by the principle and co-investigators affiliated with the Voyager Project, as well as links to home pages offered by investigators sharing details of their work. The Voyager home page also provides links to 50 WWW sites at JPL, NASA, and around the world; essentially providing "one-stop shopping" for net surfers interested in space science.

Planned features

The Voyager home page will incorporate three additional features in the near future. They are:

- a statistical program to provide demographics information concerning site contacts. (knowing who is accessing Voyager's home page will assist in tailoring the information for the target audience)
- an online questionnaire to facilitate a dialogue with page-users regarding desired modifications
- a student section to highlight student projects, including descriptions, results, etc., of Voyager-based student projects, and, perhaps, a student art gallery, where art work inspired by Voyager-captured images can be displayed

For further information about the Voyager Project home page contact the author at:

gary.l.spradlin@jpl.nasa.gov

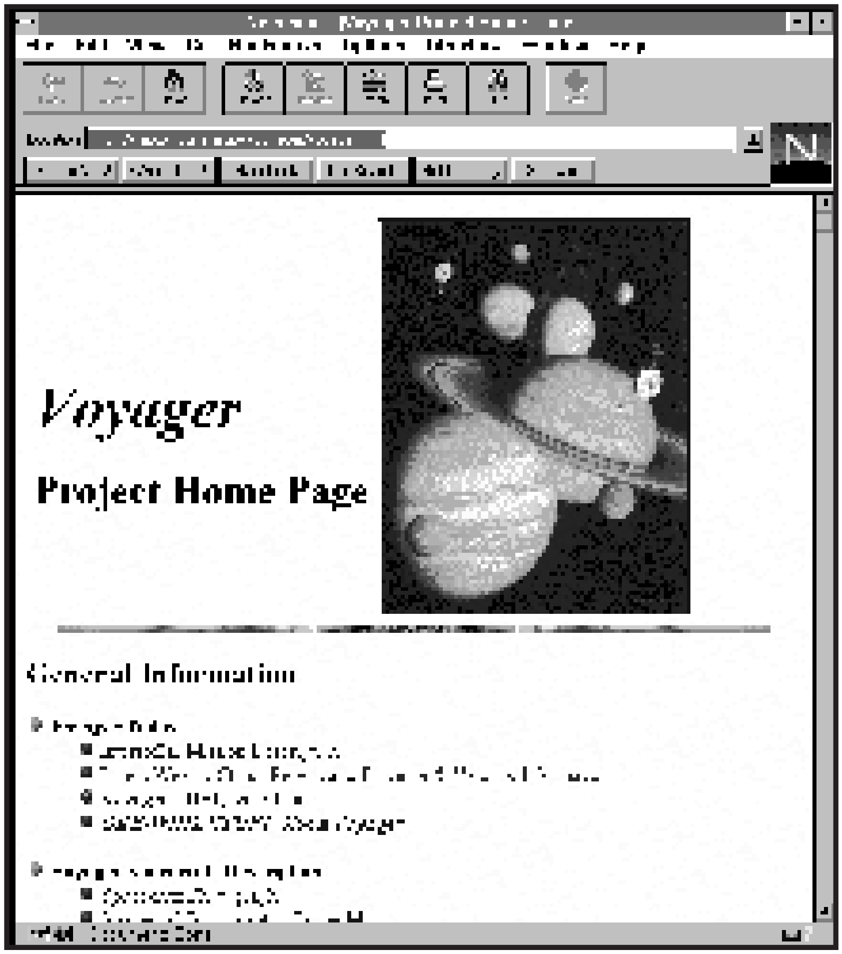

Figure 1. Voyager Project Home Page (http://vraptor.jpl.nasa.gov/voyager/voyager.html)

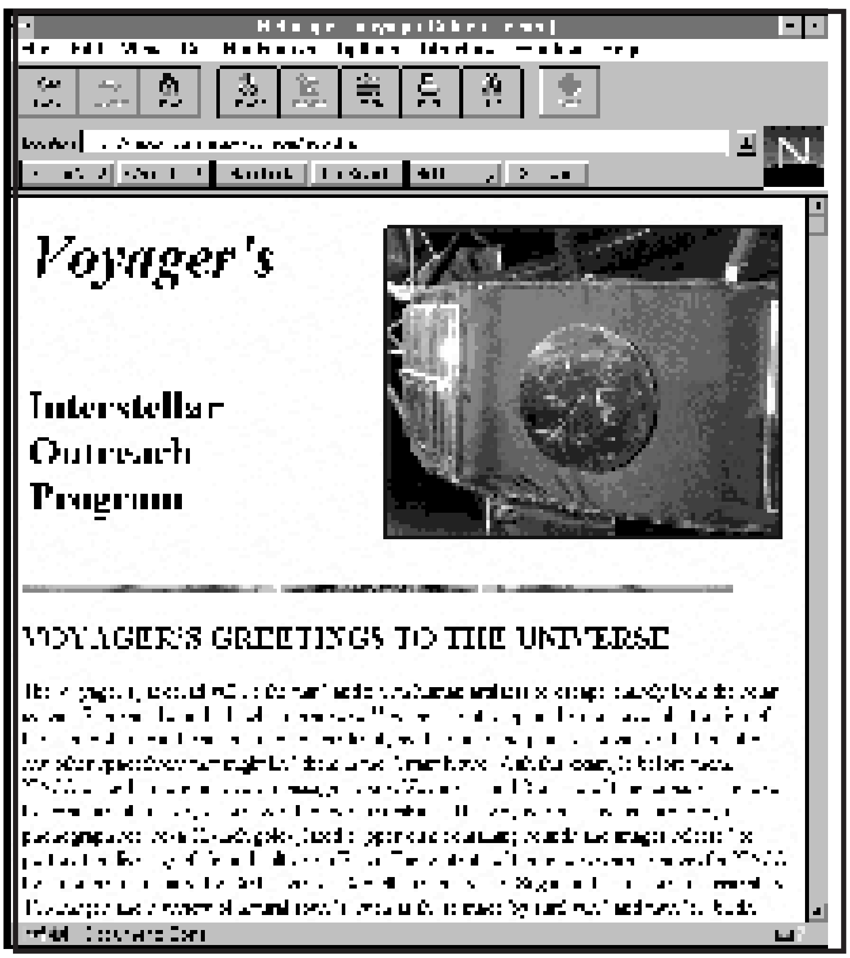

Figure 2. Voyager's Message to the Universe(http://vraptor.jpl.nasa.gov/voyager/record.html)